PB84-151497

Technical Assistance Program Report Consideration of the Resource Recovery Option in Colorado

Hart (Fred C.) Associates, Inc., Denver, CO

Prepared for

Environmental Protection Agency, Denver, CO

May 82

U.S. Department of Commerce
National Technical Information Service
NTIS

EPA 908/6-82-006

United States
Environmental Protection
Agency

Region VIII
1860 Lincoln Street
Denver, Colorado 80295

MAY, 1982

Solid Waste

PB84-151497

EPA

A TECHNICAL ASSISTANCE PROGRAM REPORT

CONSIDERATION OF THE RESOURCE RECOVERY OPTION IN COLORADO

REPRODUCED BY
NATIONAL TECHNICAL
INFORMATION SERVICE
U.S. DEPARTMENT OF COMMERCE
SPRINGFIELD, VA. 22161

TECHNICAL REPORT DATA
(Please read Instructions on the reverse before completing)

1. REPORT NO.
EPA 908/6 82-006

2.

3. RECIPIENT'S ACCESSION NO.
PB84 151497

4. TITLE AND SUBTITLE
TECHNICAL ASSISTANCE PROGRAM REPORT
CONSIDERATION OF THE RESOURCE RECOVERY OPTION IN COLORADO

5. REPORT DATE
MAY 1982

6. PERFORMING ORGANIZATION CODE

7. AUTHOR(S)

8. PERFORMING ORGANIZATION REPORT NO.

9. PERFORMING ORGANIZATION NAME AND ADDRESS
FRED C. HART ASSOCIATES, INC.
MARKET CENTER
1320 - 17TH STREET
DENVER, COLORADO 80202

10. PROGRAM ELEMENT NO.

11. CONTRACT/GRANT NO.
EPA 68 01 4992

12. SPONSORING AGENCY NAME AND ADDRESS
WASTE MANAGEMENT BRANCH
U.S. ENVIRONMENTAL PROTECTION AGENCY
1860 LINCOLN STREET
DENVER, COLORADO 80295

13. TYPE OF REPORT AND PERIOD COVERED
FINAL

14. SPONSORING AGENCY CODE

15. SUPPLEMENTARY NOTES

16. ABSTRACT

This report surveys the current Solid Waste Management in the State of Colorado. A comparison of landfill disposal with Resource Recovery in terms of costs and other factors are made. Roles and implications of State and local governments in the field of Resource Recovery are defined.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
RESOURCE RECOVERY SOLID WASTE MANAGEMENT OPTIONS IN COLORADO COMPARISON OF LANDFILL AND RESOURCE RECOVERY OPTIONS	VAIL, COLORADO, TELLER COUNTY, COLORADO UNITED STATES EAGLE COUNTY, CO HINSDALE COUNTY, CO DENVER METROPOLITAN AREA BOULDER COUNTY, CO DENVER COUNTY, CO	

18. DISTRIBUTION STATEMENT
RELEASE TO PUBLIC

19. SECURITY CLASS *(This Report)*
UNCLASSIFIED

20. SECURITY CLASS *(This page)*
UNCLASSIFIED

21. NO. OF PAGES
155

22. PRICE

United States
Environmental Protection
Agency

Region VIII
1860 Lincoln Street
Denver, Colorado 80295

Solid Waste

EPA 908/6-82-006

MAY, 1982

EPA

A TECHNICAL ASSISTANCE PROGRAM REPORT

CONSIDERATION OF THE RESOURCE RECOVERY OPTION IN COLORADO

A TECHNICAL ASSISTANCE PANELS PROGRAM REPORT:

CONSIDERATION OF THE RESOURCE RECOVERY OPTION IN COLORADO

Prepared for:

U. S. Environmental Protection Agency
Region VIII
1860 Lincoln Street
Denver, Colorado 80295

Prepared by:

Fred C. Hart Associates, Inc.
Market Center
1320 17th Street
Denver, Colorado 80202

May, 1982

CONSIDERATION OF THE RESOURCE RECOVERY OPTION IN COLORADO

ENVIRONMENTAL PROTECTION AGENCY REGION VIII

Public Law 94-580 - October 21, 1976

Technical assistance by personnel teams. 42 USC 6913

RESOURCE RECOVERY AND CONSERVATION PANELS

SEC. 2003. The Administrator shall provide teams of personnel, including Federal, State, and local employees or contractors (hereinafter referred to as "Resource Conservation and Recovery Panels") to provide States and local governments upon request with technical assistance on solid waste management, resource recovery, and resource conservation. Such teams shall include technical, marketing, financial, and institutional specialists, and the services of such teams shall be provided without charge to States or local governments.

This report has been reviewed by the Project Officer, EPA, and approved for publication. Approval does not signify that the contents necessarily reflect the views and policies of the Environmental Protection Agency, nor does mention of trade names or commercial products constitute endorsement or recommendation for use.

Project Officer: William Rothenmeyer

TABLE OF CONTENTS

Page

LIST OF TABLES v

LIST OF FIGURES vi

CHAPTER I - BACKGROUND AND INTRODUCTION

- Introduction 1
- Background of the Study 2
- Perspective of this Report 4

CHAPTER II - OVERVIEW OF EXISTING SOLID WASTE MANAGEMENT OPTIONS IN COLORADO

- Characteristics of the Solid Waste Stream 8
- Landfilling Operations in Colorado 11
- Waste Management System Costs 18
- Statewide Resource Recovery Operations 22
- Studies and Efforts Pertaining to Resource Recovery Alternatives 27
- Representative Communities 30
  - Denver 30
  - Loveland 37
  - Montrose 41
  - Vail 43

CHAPTER III - CONSIDERATION OF THE RESOURCE RECOVERY OPTION

- Consideration of Resource Recovery as a Viable Option 48
- Factors Affecting Resource Recovery Feasibility 50
- Resource Recovery Option Comparison 55
  - Source Separation 59
  - Incineration with Energy Recovery 61
  - Combination of Source Separation and Incineration 63

CHAPTER IV - COMPARISON OF LANDFILL AND RESOURCE RECOVERY OPTIONS

- Rationale and Basis for Analysis 69
- Resource Recovery as a Partial Solution to Both Solid Waste and Energy Problems 70
- Land Savings through Landfill Diversion 74
- Cost Comparison of Options 75
- Resource Recovery Scenarios 76
- Analysis of Scenarios 78

CHAPTER V - POLICY IMPLICATIONS OF THE ANALYSIS

- Potential State Government Roles 92

TABLE OF CONTENTS (Continued)

Potential County and Municipal Government Roles 99
State Commitment to Resource Recovery 100

CHAPTER VI - CONCLUSIONS AND RECOMMENDATIONS

Conclusions 103
Recommendations 104

APPENDICES

I. Costs and Returns of Solid Waste Disposal in Sanitary Landfils.............................. 105

II. Further Sources of Resource Recovery Information 111

III. Environmental Compliance of Waste-to-Energy Facilities in Colorado 117

IV. Nottingham, New Hampshire Framework for Developing The Costs of Recycling 133

V. Glossary of Solid Waste Management and Resource Recovery 142

LIST OF TABLES

Table Page

1 Selected Waste Generation Rates 9

2 1980 Estimated Average Solid Waste Composition 12

3 Estimated Colorado Landfill Costs 19

4 Resource Recovery Organizations in Colorado 24

5 Residential Solid Waste in the City and County of Denver 32

6 Denver County Waste Generation 34

7 Refuse Collected by the City of Loveland in 1980 39

8 Montrose Total Waste Generation (1981) 42

9 Solid Waste Generation in Vail, Colorado 44

10 Resource Recovery System Rating Criteria 57

11 Resource Recovery System Rating 58

12 Factors Affecting Source Separation and Incineration Potential in Colorado 66

13 BTU and Fuel Savings Adjustment Factors 73

14 Recycling Scenarios 77

15 Potential Energy Savings and Revenues from Recycling the Maximum Practical Percentage of Solid Waste in Four Communities 79

16 Vail or Montrose Drop-Off Center Cost Analysis 81

17 Loveland Aluminum Buy-Back/Drop-Off Cost Analysis 82

18 Cost Analysis for a 450 Ton per Day Denver Waste-to-Energy Facility 87

19 Cost Analysis for a 25 Ton per day Incineration Facility 89

20 Summary of Resource Recovery Analyses 91

21 Effect of Various Incentives on Decision-Making 95

LIST OF FIGURES

Figure — Page

1 Economic Development and Resource Recovery Cycle 3

2 Colorado Regulatory Framework for Landfilling 16

3 Projected Costs of Landfilling vs. Resource Recovery 21

4 Seasonal Variation of Three Communities' Waste Streams 33

5 Environment Conducive to Resource Recovery 49

6 Factors Affecting Resource Recovery Implementation 51

7 Relative Significance of Identified Impediments to Waste-to-Energy Facilities 56

8 Heat Value of Selected Waste Stream Components 71

9 Financial Comparison of Recycling Systems in California 85

I. BACKGROUND AND INTRODUCTION

Introduction

Solid waste management has traditionally received a low priority in budgets and planning processes throughout the country. Considered to be an "out-of-sight, out-of-mind" problem, labor, capital and other resources of local governments have generally been allocated to other needs and services.

The solid waste problems of the nation have begun to be recognized over the past few years with the passage of the Resource Conservation and Recovery Act (RCRA) and associated regulations. While some of these solid (non-hazardous)* waste problems are now recognized, they are still difficult to deal with because of the increasing emphasis on lessening government intervention into services and products which can be regulated primarily by market (price, supply and demand) considerations. The nature of many solid waste management problems (such as environmental, health and other concerns related to siting and operation of landfills) are, however, insidious. They may not be immediately evident and/or they may be more serious than appearance alone indicates. This is especially true in the urban areas of the country where the scope of the problem is especially significant; however, less densely populated and rural areas cannot be overlooked in recognition of the overall problem. In Colorado, 99 percent of the estimated 6,000 tons of garbage generated per day is disposed of in landfills. In many instances, Colorado local governments do not have the financial or technical resources to resolve or avoid waste management problems.

Awareness of current difficulties and the potential for future problems has led to the consideration of resource recovery as an alternative to traditional waste management techniques such as landfilling. Resource recovery is a term used in resource and energy management to describe the retrieval of economically usable energy or materials from wastes (see Figure 1). The two principal approaches to resource recovery consist of conversion (e.g., the recovery of resources through the conversion of wastes to energy -- heat and fuel) and recycling (e.g., the separation of a waste material which can then be reused). Primary benefits of resource recovery include:

---

* RCRA primarily addresses the management problems and issues of hazardous wastes. RCRA does, however, establish several important solid waste initiatives in Subtitle D such as the upgrading of inadequate disposal sites and minimum national solid waste standards to be regulated at the local and state government levels. This study is concerned only with solid (non-hazardous) waste problems.

- conservation of valuable and scarce energy and material resources;
- reduction in the quantity of solid wastes which must be disposed by a community;
- reduction in the environmental problems of solid waste disposal such as surface and groundwater contamination, odors, the use of land for disposal sites, methane gas hazards, and aesthetic considerations; and
- energy conservation through substitution of recycled materials for virgin materials (less energy is required to produce most industrial materials from scrap than from virgin sources).

However, resource recovery consideration and/or implementation has not been successful in many situations. This has been due to a variety of factors including:

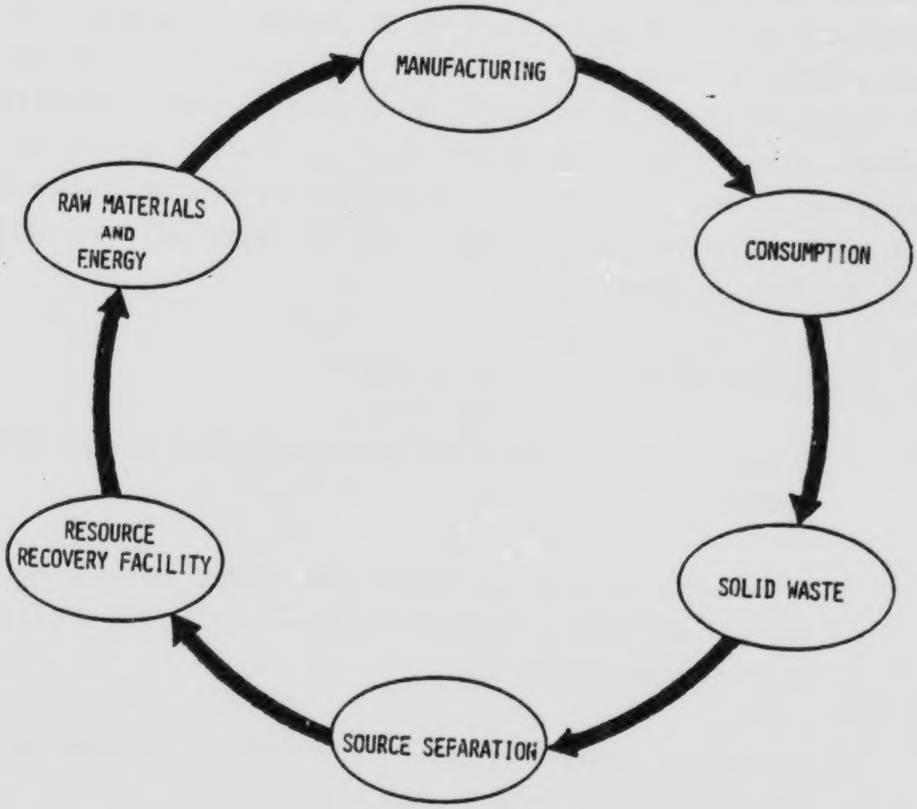
- inadequate information on which to make decisions;
- failure to consider resource recovery as a management alternative; and
- the number and diversity of factors affecting resource recovery feasibility.

Background of the Study

In an attempt to better understand some of the issues, concerns and plan-

FIGURE 1

ECONOMIC DEVELOPMENT AND RESOURCE RECOVERY CYCLE



SOURCE: U. S. Conference of Mayors

ning considerations of resource recovery, the State of Colorado Department of Health has requested assistance through the U.S. Environmental Protection Agency's (EPA) Technical Assistance Panels Program. This program makes expertise and assistance available to State and local governments in accordance with the Resource Conservation and Recovery Act (RCRA) of 1976, Section 2003. EPA has directed Fred C. Hart Associates, the EPA Region VIII panels contractor, to conduct a study of solid waste managment in the State of Colorado and an assessment of the potential for incorporation of resource recovery strategies into the management system. The scope of the study was limited to consideration of solid wastes issues and is not meant to include an analysis of similar hazardous waste concerns. Recovery and secondary use of waste oil was also specifically excluded from the study.

Objectives of this analysis include:

- to survey the current solid waste management system in the State (see Chapter 2);
- to identify and analyze factors that affect resource recovery feasibility and to discuss resource recovery operations that can be used in Colorado (see Chapter 3);
- to compare landfill disposal with resource recovery in terms of costs and other factors (see Chapter 4); and
- to evaluate some of the potential roles and implications of State and local government involvement encouraging resource recovery (see Chapter 5).

Perspective of this Report

Several factors affecting the perspective and scope of this report should be noted. Because of limited resources, this analysis is based almost exclusively on the use of existing information. Original research and analysis to fill data gaps was not possible within the scope of this project. Information which is current, relevant and specific to Colorado on the above-described topics, however, is very limited. One of the primary restraints on consideration of resource recovery as a solid waste management option is the lack of even the most basic information upon which to base decisions. This study is not meant to be a statewide market survey or a series of feasibility studies; it is, rather, an attempt at understanding the problem and identifying those issues which limit the timely consideration of resource recovery as a solid waste management option. Resource recovery is not a solid waste management panacea; it is clearly not appropriate in every situation. However, it should be evaluated as a possible alternative to landfilling of wastes. In this regard, resource recovery should be considered as one facet of the overall goal of extending landfill operations by diverting wastes from the landfill. It should, ideally, be part of a comprehensive program which includes:

- minimizing waste generation (source reduction);
- litter control;
- recycling;
- reclaiming; and
- proper design, maintenance and operation of landfills for those materials that must be thrown away.

In addition to the two general resource recovery approaches of recycling or conversion of solid wastes, there are two somewhat conflicting philosophical viewpoints on the proper application and implementation of resource recovery. One approach can be termed the ethical, environmental philosophy in which the prevailing belief is that resource recovery is an important environmental goal, and that it should be encouraged and implemented to a wide extent (as much of the solid waste stream as possible) even if government subsidies are required to provide an economic stimulus to the private market. The other approach could be termed the entrepreneurial philosophy, in which resource recovery should be implemented and can only be justified when market forces allow. The latter approach generally shuns government aid or assistance and would stress the importance of a commodity-by-commodity, case-by-case perspective on which materials within the waste stream are appropriate for resource recovery at a particular point in time. There is validity in both approaches.

Government, as the provider of basic and necessary public services, has the responsibility to make appropriate solid waste management decisions which are in the realm of social goals such as public health protection and resource management. Additionally, government must be concerned with the costs, benefits and risks of maintaining existing wasteful practices. If a portion of the waste stream is diverted from the landfill today, less land will be needed in the future when land costs are very high. The private sector, however, has the key role in determining the allocation of resources in a capitalistic economy. This report will not pursue this issue but will reflect the attitude that a balance between the two approaches can and must be made.

II. OVERVIEW OF EXISTING SOLID WASTE MANAGEMENT OPERATIONS IN COLORADO

This chapter will provide an overview of existing solid waste management practices in the State of Colorado. In the first section, data regarding per capita waste generation rates in different counties of the State are summarized and a general characterization of waste composition is provided. Per capita waste generation rates and waste composition are both important components of a solid waste management assessment, since they affect such factors as landfill operation costs and, hence, the viability of resource recovery alternatives.

In the next section, landfilling of solid wastes in Colorado is examined. Current and future issues associated with this method of solid waste management are identified. Included in this discussion is a brief outline of the regulatory framework and policy considerations affecting current landfilling practices.

The third section consists of a general discussion of solid waste management costs, an obvious major influence on the waste management options considered by decision-makers. The cost trends which should encourage the consideration of resource recovery are identified and discussed.

In the fourth section, existing resource recovery operations throughout the State are summarized.

In the final section, a general characterization is provided of current solid waste management operations for four types of communities in Colorado: an urban area; a medium-sized city; a typical town; and a resort community. These representative communities are Denver, Loveland, Montrose, and Vail, respectively. These areas were chosen for specific examination of solid waste issues for several reasons. Each is an example of a characteristic type of community which exists in Colorado and each has a somewhat different set of conditions which affect solid waste management. They were also chosen because, in contrast to many locales, information concerning solid waste volumes, collection and costs was available. Also, the four communities exhibited characteristic geographical and topographical variation that is a significant factor in attaining a clear picture of solid waste issues in Colorado. These particular situations can clarify issues and identify potential possibilities and problems under similar conditions.

Information provided in this chapter is based on a review of the limited data available from existing literature sources. To the extent possible, telephone interviews were used to provide estimates in areas where data were scarce or nonexistent. An attempt has been made to identify major data gaps which significantly impede a comprehensive and responsible waste management planning process. For the purposes of this study, general assumptions have been made, as necessary, or average national figures utilized to overcome any data gaps that would prevent the assessment process.

Characteristics of the Solid Waste Stream

Waste Generation. The weight and volume of waste is typically estimated based on the population, with a separate estimate of special wastes determined more by the specific locale or economy. Waste generation is an important factor affecting disposal costs and options in any solid waste management system. Per capita waste generation rates refer to the average amount of solid waste (usually expressed in pounds) generated per person per day in a specified area. This rate commonly accounts for all waste from the three major waste categories -- commercial, industrial, and residential waste streams. Typically, estimates of per capita waste generation do not include demolition or bulky wastes, since there is significant variability both in the weight and volume of these wastes from locale to locale and on a seasonal basis.

Table 1 provides a summary of estimated per capita waste generation rates for the nation as a whole and for specific counties and communities in Colorado for which data were available. These rates, which are based on waste generated from all three waste categories (residential, commercial, and industrial) vary from a low of 2.8 lbs./person/day in Vail, Colorado to a high of 6.5 lbs./person/day in urban Denver. Such figures reflect the widely accepted principle that per capita waste generation increases with population density, due to the concomittant increase in commercial and industrial activities associated with urbanization.

TABLE 1

SELECTED WASTE GENERATION RATES

Waste Generation Rate (lbs./capita/day)	Area	Character of Area
2.8	Vail, Colorado	Resort
3.0	Teller County, Colorado	Rural
3.5	United States[1]	Inclusive
3.9	Eagle County, Colorado[2]	Rural-Resort
4.0	Hinsdale County, Colorado	Rural
4.0	Archuleta County, Colorado	Rural
4.1	Clear Creek County, Colorado	Rural
4.4	Denver Metropolitan Area[3]	Urban
4.7	Boulder County, Colorado	Urban
5.0	Larimer County, Colorado	Urban
6.5	Denver County, Colorado	Urban

Source: 1. USEPA

2. Resource Recovery Feasibility Analysis for Eagle County, Co. Franklin Associates, Ltd., July 1980

3. 1975 estimate. Feasibility Analysis for Resourse Recovery from Solid Waste. The Ralph M. Parsons Company, March 1976

Sources for all other figures: Fred C. Hart Associates, Inc., 1981.

The data that is summarized in the table also indicate that two of the lowest per capita waste generation rates (exclusive of the national average), 2.8 and 3.9 lbs./person/day for Vail and Eagle County respectively, occur in resort areas which typically experience tremendous seasonal fluctuations in their population. For example, the population including tourists in Vail ranges from a total of 20,000 people during the ski season to 15,000 during the summer months and dwindles to 9,000 in the Spring and Fall. Low per capita waste generation rates for resort areas often disguise seasonally high generation periods, which, when coupled with a small permanent population, can create unique solid waste management problems.

The Vail estimate of 2.8 lbs./person/day was developed by dividing the yearly total amount of solid wastes by a weighted average of Vail residents (permanent plus tourists) on a seasonal basis. The weighted average of approximately 13,200 was derived from a population of 9,000 for half a year, and 20,000 and 15,000 for one-quarter year each. Another technique for determining per capita daily waste generation for comparative purposes is to consider tourist-generated solid waste separately as commercial solid waste. In this case the total amount of waste would be attributed to the permanent-resident population of the area (assumed to be 9,000) as a component of the municipal waste stream as in Denver and other areas. In Vail, this method of calculating daily per capita waste generation results in a waste generation rate estimate of 4.0 lbs.

Waste generation rates as depicted in Table 1 are affected by demographic and economic factors including population density (urban/rural), and the degree of commercial, industrial and recreational activities.

Finally, it must be emphasized that accurate waste generation estimates are often difficult to develop, due to the limited amount of reliable data regarding such key factors as total waste volumes and the population of a solid waste service area. Total waste volume estimates are undependable since few landfills in Colorado have scales and few public or private collection services keep comprehensive and accurate records. Moreover, a large portion of the waste deposited at landfills is hauled by individuals, and no records exist regarding the number of users and volumes of these wastes. The variety of options regarding waste collection -- municipal collection services, private collection services, and individual haulers -- creates obstacles to accurate record keeping.

Waste Composition. Waste composition is another important factor in characterizing the solid waste management system. Composition figures provide estimates of the amounts and types of materials in the waste stream. This is significant in assessing the viability of resource recovery. Waste composition estimates provide information on the potential for source reduction, recycling and energy conversion. Identification of the components of the solid waste stream may suggest appropriate resource recovery options such as methane recovery from landfills containing a high proportion of organic wastes.

Waste composition, as with waste generation, differs significantly with the degree and type of commercial/industrial activity in an area. Urban areas which support greater population densities and concurrently a greater variety of commercial and industrial activities will generate a more diverse waste stream than areas which are more homogeneous in terms of economic activities (such asrural-agricultural areas). However, the complexity of rural waste streams resulting from special wastes such as septic tank pumpings and agricultural wastes (pesticide containers, dead animals, etc.) causes difficult disposal problems.

Unfortunately, there are no quantitative studies on local waste composition within Colorado. Consequently, national waste composition figures were used for this initial planning effort. Table 2 presents the most recent national figures regarding solid waste composition.

Landfilling Operations in Colorado

Overview. At the present time, 99 percent of all solid waste generated in Colorado is disposed by landfilling. Colorado's citizens, businesses, and industries create an estimated 6,000 tons of solid waste per day, requiring at least 12,000 cubic yards of space for land deposition. In 1981, there were 206 public sanitary landfills in active operation, versus an estimated 300 to 400 landfills or dumps in operation 10 years ago. These met the needs of a State with significantly less industrial and commercial activity and a population 31 percent smaller than that of the present.

TABLE 2

1980 ESTIMATED AVERAGE
SOLID WASTE COMPOSITION - PERCENT BY WEIGHT

Components	
Paper Products	31.9
Ferrous Metals	7.5
Non-ferrous Metals	1.3
Glass	9.7
Plastic	4.0
Yard	18.0
Food	16.7
Wood	3.9
Miscellaneous	7.0
	100.0

Source: Franklin Associates, Ltd. based on calculations made annually for the U.S. Environmental Protection Agency.

The significant decrease in the number of landfills is primarily a result of increased Federal and State regulation of solid and hazardous waste management. Enactment of the Federal Resource Conservation and Recovery Act of 1976 and the State Solid Waste Disposal Sites and Facilities Act of 1972 mandated stricter environmental controls which resulted in the closure of numerous sites. Moreover, the higher operational and maintenance costs associated with increased regulation increased a trend towards larger, centralized solid waste management facilities which could economically support the necessary equipment and facilities for effective operation.

Moreover, as the number of available sites decreased, waste disposal at the remaining sites has greatly increased, placing a heavy strain on existing sites and a consequent reduction in each of those site's overall lifetime expectancy. As a result, landfills throughout the State are rapidly reaching maximum capacity. The Denver Metropolitan area, Colorado Springs, Fort Morgan, Grand Junction, Silverton, Pagosa Springs, Estes Park, Boulder, and Eagle County, as well as many other locations, face closure of one or more major solid waste disposal sites within one to five years.

In addition, many current sites are still experiencing serious operational problems. Of the 61 landfills in Colorado serving over 5,000 persons, 21 sites or 35 percent, were in violation of State and Federal requirements at the time of their last inspection. Of the 145 sites serving less than 5,000 people, 94, or 65 percent, were found to be out of compliance. Where problems are severe or costly, many of these sites may opt or be forced to close as a result of their failure to meet government regulations and growing local opposition to environmental contamination or degradation. Moreover, many of those landfills currently in compliance will close in the near term due to exhaustion of their capacity.

Constraints to Siting. As the number of available landfills dwindles, numerous siting problems impede the expeditious progress of finding suitable, new sites. These problems are primarily caused by increased use of land for residential and commercial purposes creating strong competition for available land space; physical and climatological constraints which render much available land unsuitable for siting; and rapidly growing public opposition to the development of sites near residential communities of any size.

For example, in such densely populated locations as the Denver metropolitan area with tremendous waste volumes and disposal needs, limited suitable land is available for landfilling activities, costs are high, and strong public opposition is a common ingredient in siting attempts. Residents nearby prospective sites complain of lowered property values, and voice strong concerns regarding proper operation and management, as well as numerous health, safety, and aesthetic issues. Air contamination, blowing litter resulting from high winds, fires, odor problems, vectors, unsightly views, and greatly increased vehicular traffic are all commonly cited problems. Residents in areas far from a landfill site object to the potential for contamination of groundwater and public water supplies.

In rural or smaller communities, problems range from siting constraints imposed by mountainous terrain and severe winter weather which make available land unsuitable, to economic constraints arising from the inability of low population densities to support the costs associated with solid waste management operations.

Recent Landfill Trends. Due to the combination of constraints and forces described above, two noteworthy solid waste management trends should be discussed:

- the regionalization and centralization of landfills; and
- the location of landfills at greater distances from the population center they serve.

These interrelated trends have occured through:

- the ability to take advantage of economies of scales with a greater waste volume in both collection and disposal;
- the avoidance of waste management inefficiencies caused by duplication of equipment, labor and other resources at individual landfills;
- the avoidance of waste management problems such as siting and environmental constraints associated with a larger number of separate, inadequately operated facilities.

Additionally, Federal guidelines and Colorado law and regulations encourage these trends in recognition of these benefits.

State Regulatory Framework for Landfilling Practices. The State Health Department and the municipal and/or county government share the responsibity for solid waste management according to Colorado's Solid Waste Disposal Sites and Facilities Act (see Figure 2). Under this legislation, the Health Department is responsible for assuring safe location, design, construction and operation of sites and facilities. In accordance with State land use policies and laws, most of the siting decision and analysis authority is held by the county. The responsibility for land use (through zoning and other mechanisms) belongs to local government. Additionally, assurance that disposal capacity of landfills, incinerators or recycling operations is adequate to process the solid waste stream is generally perceived by the public as a local government responsibility.

State of Colorado legislation pertaining to the siting of solid waste disposal facilities is found in Title 20, Article 20, Part 1 and associated regulations. Siting of a facility requires:

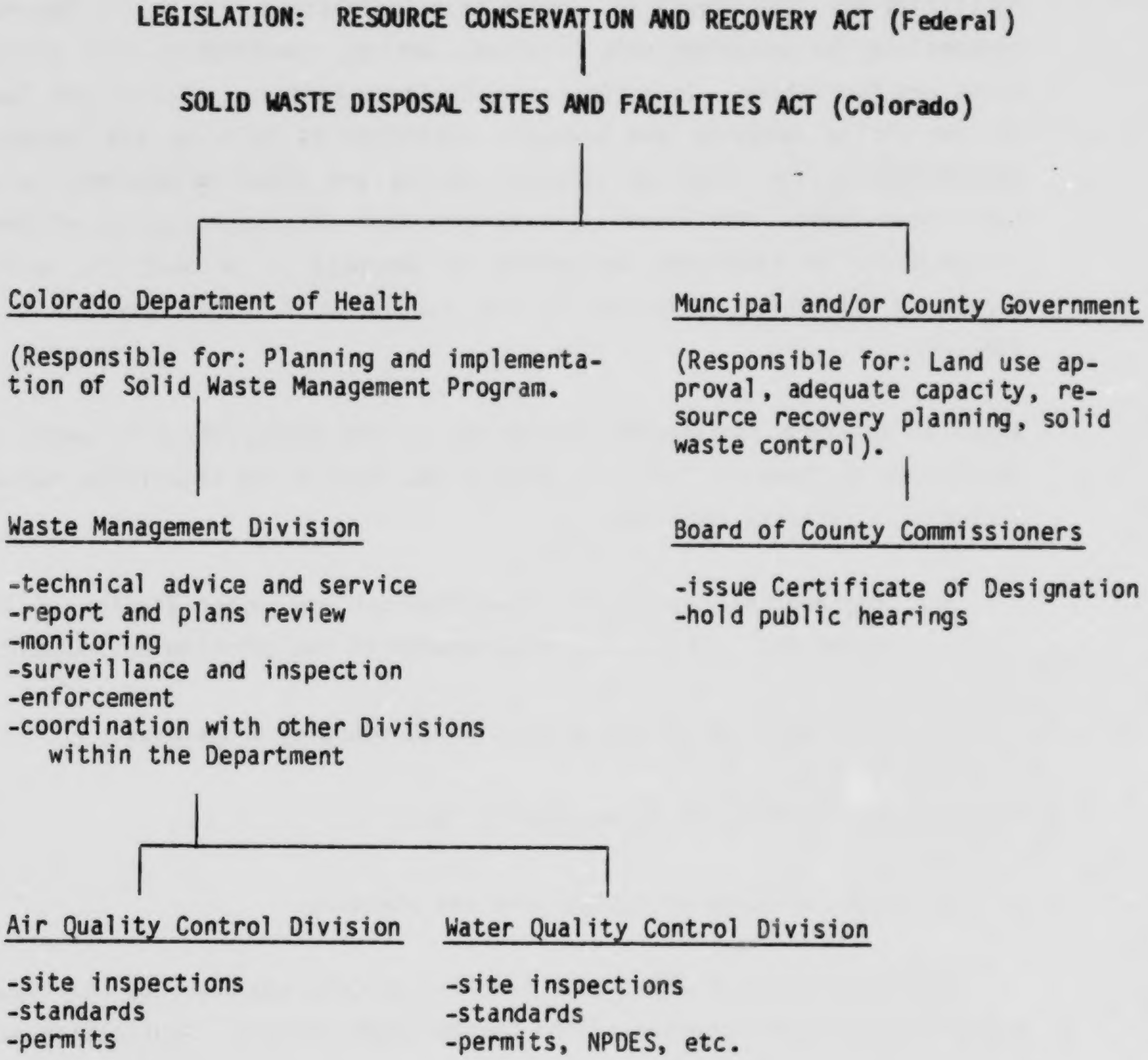
- engineering, geological, hydrological and other studies of the proposed facility and its relationship to the existing environment;
- consideration of the effects on surrounding properties;
- convenience and accessibility; and
- consideration of county land use planning.

Legal operation of any public landfill in Colorado requires the issuance of a certificate of designation by the County Commissioners. Application materials submitted by the prospective operator to obtain this certificate include the above listed information, plus:

- description of the proposed facility (including design, construction, and operation considerations); and
- hours of operation, management data, and rates.

FIGURE 2

COLORADO REGULATORY FRAMEWORK FOR LANDFILLING



LEGISLATION: RESOURCE CONSERVATION AND RECOVERY ACT (Federal)

SOLID WASTE DISPOSAL SITES AND FACILITIES ACT (Colorado)

Colorado Department of Health

(Responsible for: Planning and implementation of Solid Waste Management Program.

Waste Management Division

-technical advice and service
-report and plans review
-monitoring
-surveillance and inspection
-enforcement
-coordination with other Divisions within the Department

Air Quality Control Division

-site inspections
-standards
-permits

Water Quality Control Division

-site inspections
-standards
-permits, NPDES, etc.

Muncipal and/or County Government

(Responsible for: Land use approval, adequate capacity, resource recovery planning, solid waste control).

Board of County Commissioners

-issue Certificate of Designation
-hold public hearings

Source: Fred C. Hart Associates, Inc.

Other information can be required by the County Commissioners as they deem necessary. The County Commissioners must submit the application materials to the State Health Department for review and for recommendation as to approval or disapproval. Before a certificate can be issued by the county, the application must be approved by the State Health Department. Information must be presented at a public hearing to allow for appropriate community and public participation. Once granted, the Certificate of Designation can be suspended or revoked for violation of minimum standards. The State Health Department also participates in this area, to the extent that it provides inspections of landfills and has the authority to take action to mitigate threats to public health or the environment.

When a landfill site is within the limits of a city or incorporated town, the facility must be approved and designated by the city or town as well as the State Health Department and the County Commissioners. The governing body of any city or incorporated town may designate and approve by ordinance a solid waste disposal site within its corporate limits as its exclusive waste disposal site and facility.

Local governments are allowed to establish solid waste districts under current law but to date no districts have been formed. Funds from taxes or direct charges levied by a district may be used for solid waste planning and operations. The State, through the budgetary process, can allocate funds to levels of government (primarily for technical assistance) although the possibility of securing these funds is very limited at present.

The Colorado Department of Health (CDH) is guided in its solid waste management activities by Colorado's Management Plan for Solid and Hazardous Wastes. This plan identifies management goals and demonstrates for the U.S. EPA the State's successful fulfillment of certain RCRA requirements.

The plan has two main goals pertaining to solid waste management. The first goal is to assure the proper siting and operation of solid waste sites by: minimizing threats to the public health and environment, especially groundwater; excluding hazardous materials from sites unless sites are specifically approved for such disposal; restricting land use of closed sites for several decades; and preventing methane gas hazards. Authorization to attain this goal is provided. The Solid Waste Act directs the CDH to prohibit the establishment of open dumps and to inventory and classify existing sites and improve or close those considered to be open dumps.

Waste Management System Costs

The major operational components of a solid waste management system are collection, transportation, and disposal. Of the three components, resource recovery (as an alternative waste disposal option) compares most directly with disposal (e.g., at the landfill). For this reason, landfill and resource recovery costs are important for the evaluation of the competitiveness of resource recovery. Accurate landfill costs, however, are difficult to obtain in most situations.

Figures presented in Table 3 are the estimated costs to disposers not to landfill operators. The cost of disposal for landfill operators cannot be accurately determined from the tipping fee charged. The tipping fee is the fee charged to the user for disposing of wastes. Variables such as solid waste density, actual landfill operating standards and proportions of compacted, uncompacted and bulk wastes would have to be known. Additionally, landfill costs estimates are complicated by:

- **Accounting practices**: Accounting manipulations often prevent specific breakdowns of costs. In the public sector, equipment, personnel and materials used in landfill management may be shared by different departments or sites. Private companies consider cost information to be confidential.

- **Subsidized Operations.** Landfilling operations can be subsidized through a variety of intentional and/or unintentional mechanisms: the accounting discrepancies referred to above; inappropriate tipping fees; or, use of public land at a reduced cost, among others;

TABLE 3

ESTIMATED COLORADO LANDFILL COSTS

Landfill	Tipping Fee ($/yd.^{3})	$/ton*
Adams County		
Landfill, Inc.	2.50	7.15
Tower Disposal	2.00	5.70
Denver - Arapahoe	1.40	4.00
Arapahoe County		
Lowry	1.60	4.60
Boulder County		
Marshall	1.60	4.60
Longmont	1.60	4.60
Douglas County		
Larkspur	.85	2.45
Colorado Disposal	1.20	3.45
Castle Rock	.85	2.45
Swayback	.85	2.45
Parker	.85	2.45
County Line	1.60	4.60
Eagle County Landfill	1.10	3.15
Garfield County Landfill	1.00	2.85
Jefferson County		
Rooney Road	1.00	2.85
Leyden	1.00	2.85
Jefferson County Landfill	1.75	5.00
Larimer County		
Larimer County Landfill	1.25	3.60
Wellington	1.25	3.60
Estes Park	1.25	3.60
Montrose County Landfill	1.50	4.30
Pitkin County Landfill	1.25	3.60
Summit County Landfill	1.05	3.00
Weld County		
Colorado Landfill	1.60	4.60

* Based upon an average waste weight of 700 lbs/cubic yard.

Source: Fred C. Hart Associates, Inc.

- **Regulatory Costs.** Operations which are not in compliance with solid waste management regulations would not reflect the future costs of landfilling. Cost can be expected to increase when landfill siting, design, and operating regulatory criteria are applied to non-compliant operations.

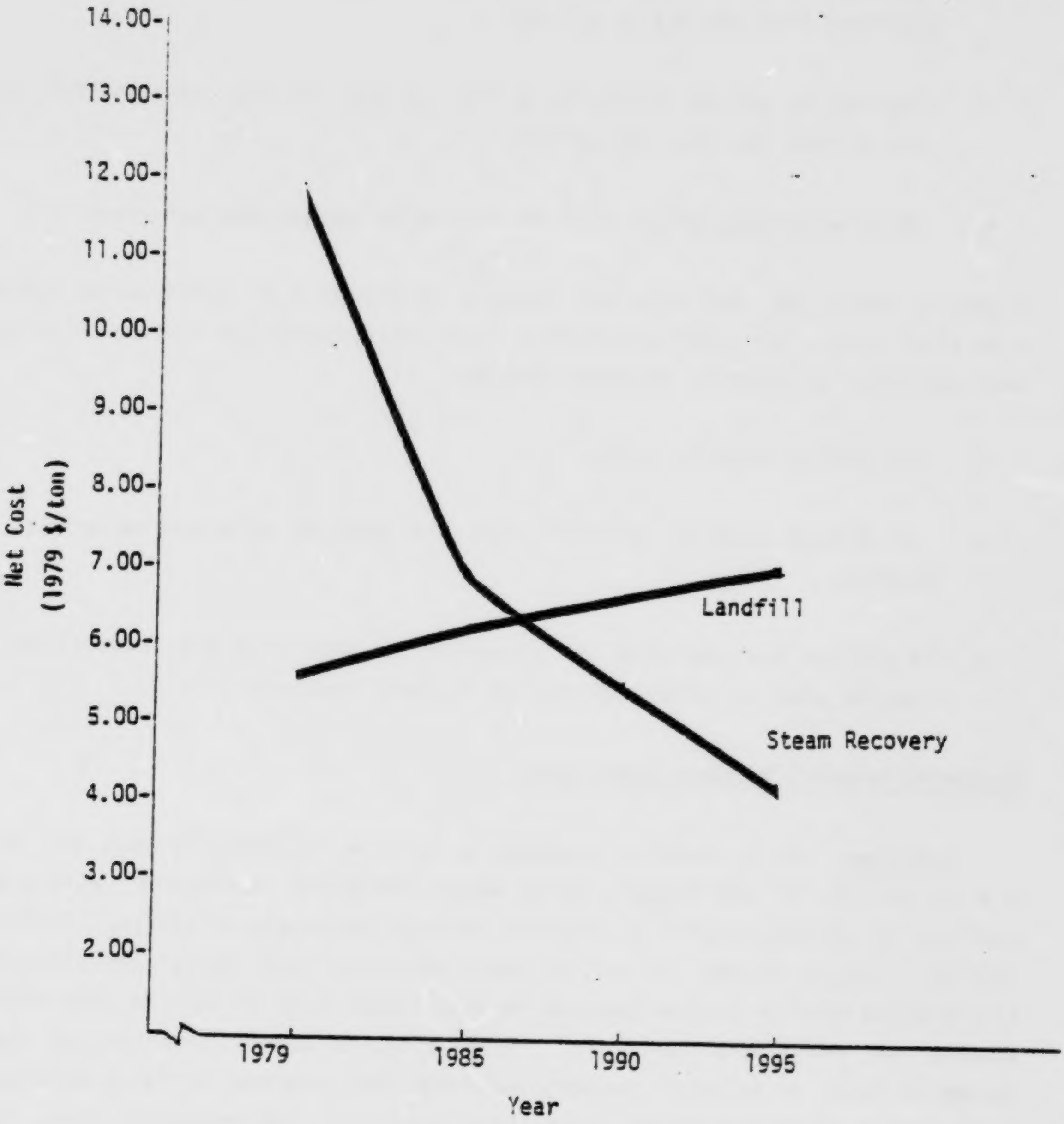
Collection and transportation costs are also important in examining the feasibility of resource recovery. Because these costs are typically 75 percent of overall waste system costs, a reduction in this cost category could be important in comparing waste management options. It should be noted that recent increases in transportation costs due to rising energy costs have been especially significant.

Generally, current disposal costs in Colorado are estimated to range from $2 to $10 per ton. Collection costs are dependent upon specific local conditions. These costs are estimated to range from $10 to $50 per ton. The data base is so limited that it is impossible to determine if these cost estimates reflect actual costs. It should be emphasized again that costs used in this report may not be directly comparable because of the differences in accounting practices and other constraints. A more thorough analysis (site visits, extensive interviews, review of local records, etc.) of waste system costs would be nessary to establish a realistic basis for comparison of waste management options (including resource recovery) within Colorado communities.

Currently, $80 million per year are spent on solid waste management in the State predicated on an average cost of $30 per ton for collection/transportation and $7 per ton for landfilling. Figure 3 illustrates the typical projected trends in costs of traditional (landfilling) disposal methods and waste-to-energy systems. This figure is based on a feasibility study performed for waste-to-energy options in Fargo, North Dakota, and would be representative of the situation faced by most communities in Colorado and other lower population density States where landfilling costs have been relatively low and where there exists little pressure to change traditional waste management procedures. If solid waste management costs continue to rise as expected, this will encourage consideration of resource recovery as a management option. With realistic assumptions of:

FIGURE 3

PROJECTED COSTS OF LANDFILLING vs. RESOURCE RECOVERY



Source: Market Study for Recovered Energy and Materials Products in Fargo, North Dakota, Gordian Associates. Prepared for U.S. EPA, 1979.

- real operating costs for landfill and resource recovery systems escalating at two percent per year ("real" cost or price escalation is defined as an increase exclusive of inflationary factors--inflation is excluded from the analysis); and

- real energy prices increasing at five percent per year through 1985, and one percent per year thereafter;

- solid waste generation rates increasing at two percent per year;

Figure 3 shows that the resource recovery option will be economically viable soon after 1985. The important factors, then, encouraging the consideration and implementation of resource recovery include:

- increasing landfill costs;

- increasing revenues accruing from the sale of recovered materials or energy;

- a savings realized from the diversion of waste from the landfill which can be used to offset the cost of resource recovery.

Statewide Resource Recovery Operations

Overview. While resource recovery activities currently account for less than 1 percent of the State's solid waste management operations, widespread interest in the development of resource recovery alternatives exists. Throughout the State, a variety of profit, non-profit, and governmental organizations are involved both in active resource recovery operations as well as feasibility studies and educational programs. Private and volunteer organizations have tended to focus on material recovery and recycling programs, while governmental and research-oriented programs focus almost exclusively on energy recovery, with or without separation of recoverable materials. Financial support for these organizations ranges from corporate, independent, and government funding to donor and all-volunteer support.

Motivating factors for these organizations are extremely diverse. Legislative mandates, and ethical and conservation considerations provide a framework for governmental as well as volunteer and non-profit organizations. In addition to such considerations, profit incentives and the assurance of commercial raw material supplies may encourage recycling efforts of private businesses and larger companies.

Materials Recovery. Table 4 summarizes current materials recovery operations in the State. Scrap metals form the backbone of existing recovery activities statewide, with paper, glass, and compost materials recovery activities operating at a smaller scale. An estimated 200 recycling centers in Colorado currently accept at least one material, most commonly aluminum cans. A very small number of organizations are "comprehensive" and accept virtually all recyclable materials including various grades of paper, cardboard, glass, aluminum, steel, waste oil and sometimes tires and plastics. Most of these facilities function as collection or pre-processing centers which ship recovered materials to other centralized facilities where actual recycling is performed.

Non-profit, comprehensive recycling groups in the State of Colorado formed the Colorado Recycling Cooperative Association (CRCA) in 1976. The purposes of the cooperative are to share expertise and equipment, and to develop a viable, integrated recycling system statewide. At the present time, there are only three active members: Eco-Cycle (Boulder); Recycle Something (Fort Collins), and the Summit Recycling Project (Breckenridge). Of those, Eco-Cycle handles the greatest volume, has the highest funding, and has the best equipment. Eco-Cycle is one of two organizations in the State that has a curbside pickup program. As such, Eco-Cycle has achieved a 25 percent participation rate among Boulder households and is capturing 5 to 9 percent of Boulder's waste stream. Eco-Cycle hopes to attain 50 percent participation following some organizational changes. Because Recycle Something and Summit Recycling rely primarily on drop-off centers to collect materials, they cannot accurately estimate participation, but it is thought to be less than 5 percent. These two organizations also make pick-ups from cooperating businesses and institutions. Recycle Something and Summit Recycling Project are suffering from a cut-off of CETA funds and general economic hardships. Group directors doubt that comprehensive recycling can pay for itself under current conditions, but they point out that landfilling has no

TABLE 4

RESOURCE RECOVERY ORGANIZATIONS IN COLORADO

I. Materials Recycling - Private

Organization	Location	Commodity
Action Oil Company	Longmont	Oil
Aero Oil Company	Denver	Oil
Albertsons	33 Colorado Locations	Aluminum cans
All Aluminum Recycling	Colorado Springs	Aluminum
Associated Grocers	Many Locations	Aluminum cans
Atlas Metal and Iron Corp.	Denver	Scrap metals
Ben Franklin Manufacturing	Golden	Oil
City Waste Paper Co.	Colorado Springs	Papers
Colorado Service Station Operators Assn.	State-wide	Oil
Coors Distributing Companies	Several Locations	Beverage containers
Esterberg, Fritz	Deer Trail	Oil
E.L. Trucking Company	Golden	Oil
Freidman and Sons	10 Locations	Paper
Golden Goats	20 locations-Denver area	Aluminum cans
Golden Recycle Company	Golden	Beverage Containers
K-2	Ft. Collins	Newsprint
King Soopers	53 Colorado locations	Aluminum cans
Lindsay L W and Sons	Denver	High grade paper
Milt Adams, Inc.	Adams City	Oil
McNeill, Hubert	Loveland	Cardboard
Mountain Chemicals, Inc.	Golden	Solvents
Muscular Dystrophy Assn.	Englewood	Oil
Natursoil	Denver	Organic wastes
Neiman Salvage and Junk	Denver	Scrap metals
One Stop Recycling	Denver	Comprehensive
Optimum Art Glass	Greeley	Glass
Osco Company	Adams City	Solvents
Pikes Peak Waste Oil Pick-up	Denver	Oil
Refinoil	Clifton	Oil
Remelt Metals	Denver	Automobiles
Reynolds Aluminum Buy Back Center	21 Locations	Aluminum cans
Safeway	106 Colorado locations	Aluminum cans
Star Industrial Supply	Denver	Clothing
Sunbelt Recycling	Colorado Springs	Glass, aluminum
Sundstrand Corp.	Denver	Plating solutions
Thoro Products	Golden	Solvents
Tri-R Systems	Denver	Comprehensive
V.M. Irvin Inc.	Canon City	Oil
Western Scrap Processing Co.	Colorado Springs	Metals

TABLE 4 (cont.)

RESOURCE RECOVERY ORGANIZATIONS COLORADO (cont.)

II. Materials Recycling-Non Profit

Organization	Location	Commodity
Boys Club	Greeley	Comprehensive
Eco-Cycle	Boulder	Comprehensive
Environmental Center	Boulder	
Everitt Junior High	Wheatridge	Comprehensive
Ft. Carson Recycling	Colorado Springs	Comprehensive
Girl Scouts	Greeley/Ft. Collins	
National Park Service Recycling Shed	Estes Park	
Park Hill Recycling Network	Denver	Comprehensive
Recycle Something	Ft. Collins	Comprehensive
San Juan Basin Resource Recovery Coop.		
San Luis Valley Senior Citizens		
Summit Recycling Project	Breckenridge	
Tri-Cycle	16 Locations	Beverage containers

* This is not presented as an exhaustive list of non-profit recycling organizations in the State. Many more organizations of various scales and activity levels exist; however, no catalog of these organizations has yet been compiled.

Source: Fred C. Hart Associates, Inc. 1981.

payback possibilities either from a cost or community service standpoint. Despite good community participation, a dedicated volunteer staff and a desire to become full-scale, it appears some funding is necessary if organizations such as these are to remain functional. The other curbside pick-up program involves a small area in the Park Hill neighborhood in Denver through which approximately 200 tons of goods were recycled last year.

A relatively new concept in Colorado is being developed by the Natursoil Company which utilizes yard and other organic wastes to produce a high quality garden compost and potting soil. In addition, Natursoil has been working with the City of Northglenn to assess the level and economics of yard waste recovery. The firm's owner believes that yard waste recycling has tremendous opportunities for expansion in the Denver area and that the outlook is good in terms of economics as well as from a waste management/resource recovery standpoint.

Among private recyclers, there are two comprehensive "buy-back" recyclers. Tri-R Systems and One Stop Recycling accept all commonly recycled materials and some unusual items. Materials accepted include all types of paper, all grades of aluminum, copper and brass, auto batteries and radiators, cardboard, negatives, and photographic fixers.

It is estimated that industrial scrap metals are almost totally recycled although scrap markets are characteristically erratic in terms of price and demand levels. In light of this situation, industrial scrap does not enter the waste stream and is not a factor in waste composition calculations. Therefore, when metals are discussed in this study, it is primarily residentially and commercially generated metal wastes such as aluminum and steel cans, to which reference is made.

Recycling the metals that are found in the household and commercial waste stream is much more difficult than recycling industrial scrap due to the small, dispersed quantities. Beverage manufactuers and distributors in the State have taken an active role in the collection and recycling of beverage containers. In 1973, the beverage industry formed Tri-Cycle which currently has 15 drop-off centers in the Denver metropolitan area. Aluminum is purchased from a wide variety of brokers and middlemen by Reynolds or Alcoa to produce new aluminum sheet for beverage cans, although these firms do not maintain local processing facilities. At the present time, a tremendous oversupply of aluminum cans has resulted in local collectors being placed on allocation. However, the decreased price of recycled aluminum resulting from an oversupplied market is leading to the consideration among manufacturers of an increase in processing capacity.

The relative percentage of glass and paper recycled in Colorado is lower than metals recycled as the glass and paper markets are less stable and less developed. A small market for glass currently exists. The Golden Recycle Company is in the process of establishing a market for glass in the Denver area for use in new glass bottles. The company currently accepts container glass and intends to triple its present demand capacity from 30 tons of glass per day to 100 tons per day.

Similarly, only a limited number of organizations are involved in paper recycling. Newsprint, office paper, corrugated cardboard, and computer paper are most often recycled of the 41 identified grades of paper. Currently, recycling of paper is hampered by the absence of nearby markets. Transportation costs may make recovery of such materials permanently or seasonally uneconomic (i.e. the demand for newsprint is highly seasonal, therefore, transportation costs can only be offset during high demand/high price periods) for Denver recyclers. Recycled newspaper is used in the production of new newsprint, toilet paper, cellulose insulation, and roofing materials; the last two items are significant in the highly seasonal demand for recycled newspaper.

The Garden State Paper Company in Denver occasionally buys small amounts of newsprint. However, the major newsprint buyers are located on the West Coast, East Coast, and in Texas and Mexico. The transportation costs for such relatively low cost commodities are often of such magnitude as to almost eliminate any potential for profit.

Studies and Efforts Pertaining to Resource Recovery Alternatives

Several resource recovery feasibility studies or plans have been recently completed or are in progress in Colorado. Often alternatives are being considered in areas where severe landfill-associated problems have been experienced or are anticipated.

For example, in Summit County, the Forest Service (which leases the landfill property to the County) mandated a 50 percent reduction in solid waste volumes deposited in the landfill. As a result, the Citizen's Committee on Volume Reduction and Recycling prepared a report considering various alternatives to meet that goal. The committee recommended that the county support a full scale recycling program to achieve the Forest Service requirement. At this time, action has not been taken on their proposals.

In Colorado Springs, following heated public opposition to expanding an existing landfill (which is anticipated to reach capacity within approximately 5 years), the City-County Waste Disposal Resource Recovery Task Force was formed. The Task Force has compiled solid waste data necessary for detailed analysis of present and future solid waste management options.

Larimer County has also examined the potential for resource recovery. The county has a functioning recycling organization so waste-to-energy was considered as a partial alternative to landfilling. The 1982 feasibility study conducted by Fred C. Hart Associates concluded that a waste-to-energy facility was not economically feasible at present due to the lack of a suitable energy consumer. However, the potential for future development is favorable.

Waste-to-energy resource recovery was also studied by Fred C. Hart Associates for Boulder, Colorado in 1981. Preliminary figures have strongly suggested that solid waste conversion would be economically competitive with landfilling costs. Interest in the City and the County is high. No further steps have been taken at this time.

In Eagle, Colorado, the town received grant monies to study the feasibility of burning municipal solid waste, construction waste, and sewage sludge to recover energy. Following initially optimistic projections, the primary energy consumer had to be dropped from further consideration. The study concluded that the economics of the project were not favorable.

The most immediately promising project is the Denver Energy Utilization System. The City and County of Denver is in the process of planning for a waste-to-energy facility with a capacity of around 450 tons per day. The economics of the project appear to be good. The project team is still in the process of developing detailed planning projections.

Methane recovery is a form of resource recovery applicable to completed landfill sites. Several large landfills are being studied as sources of methane which can be used as a fuel. Recent State legislation authorizes such uses and federal energy funds are available to develop and use landfill methane as fuel. A demonstration project is under development in Adams County. The possibility of methane recovery is also being seriously considered in Larimer and Jefferson Counties.

Some public-interest and professional groups also have organized subcommittees to study the resource recovery issue and participate in educational programs. A list of these groups is included in Appendix 2 as well as some additional information sources.

State Policy Considerations of Resource Recovery. A major goal that is identified in Colorado's Solid and Hazardous Waste Management Plan is to encourage resource recovery whenever practicable for both solid and hazardous wastes. According to the plan, The Department of Health will provide technical assistance to local governments to encourage resource recovery. The general approach is to encourage both material and energy recovery from solid waste streams. The CDH does not have funding to directly subsidize or support specific recycling programs, at the present.

The CDH also oversees the Resource Recovery Subcommittee of the Solid Waste Advisory Committee. In November 1981, the Subcommittee adopted a set of resource recovery goals for Colorado and strategies or areas for implementation were also identified. The goals are as follows:

- To promote and assist industrial and commercial roles in resource recovery.

- To develop a general information base on resource recovery.
- To encourage public involvement and participation through programs designed to increase awareness of resource recovery.
- To seek legal/legislative remedies for existing deficiencies.

This study represents a part of the process whereby the State is evaluating resource recovery as a solid waste management tool and developing an information base.

Representative Communities

Denver. Denver, the capital city of Colorado, is the largest and most densely populated urban area in the Rocky Mountain Region. As such, it is an important area for study of resource recovery potential. The Denver Metropolitan Area encompasses large portions of Adams, Arapahoe, Boulder, Denver, Douglas, Gilpin and Jefferson Counties. According to the 1980 census, the area's residents account for 55 percent or 1.6 million of the state's 2.9 million people. The City and County of Denver had a 1980 population of 491,000 or approximately 17 percent of the total state population. The majority of the regional population growth has occurred in the counties surrounding the City and County of Denver. Arapahoe and Jefferson Counties have led the region in rate of growth with population increases of 81 percent and 58 percent, respectively, between 1970 and 1980. During the same time period the population of the City and County of Denver declined by 4.5 percent. The Denver Regional Council of Governments (DRCOG) expects the population of Denver to grow in the next twenty years, reversing this trend, as downtown neighborhoods are revitalized.

Land use in the City and County of Denver is varied. The central business district portion predominantly consists of high density commercial buildings. High and very high density mixed commercial residential areas surround the central business district.

City personnel from the Department of Public Works collect refuse from residential housing of seven units or less. Private commercial haulers collect solid waste from multi-unit housing, business and industries. Table 5 presents tonnage figures for municipal and private collection of residential solid waste in the City and County of Denver. As shown in the table, city crews collected approximately 63 percent of the residential solid waste. Although private collection figures for 1980 were not available, it was assumed that the proportion of private collection remained constant, and figures developed for Table 5 were calculated on that basis.

The percentages shown in Table 5 refer only to solid waste tonnage; not necessarily the percentage of people served. The City collection system serves less than 63 percent of Denver's 491,000 people; however, since this includes single family detached dwellings, this population probably generates proportionally more than multi-unit housing residents served by commercial haulers due to the yard waste component.

Variation in yard waste is typically thought to be the major factor in seasonal variation (aside from seasonal population fluctuations). In areas where there is significant commercial and industrial activity, the seasonal variation in the total waste stream (including these components) is usually much reduced. Twenty-five percent above or below average is an accepted maximum figure. The 1980 seasonal variation of Denver's residential waste stream can be seen by examining Figure 4. The residential waste load was 26 percent below the average in February (no yard wastes) and 46 percent above average in May (large amounts of yard wastes associated with spring yard work).

Based on the tonnages presented in Table 5, the residential waste generation rate in Denver is 3.5 lbs. per person per day. The City and County of Denver weigh their compactor trucks as they enter the landfills; however, landfill operators do not require that other vehicles be weighed. Private haulers who handle commercial and industrial waste disposal also do not limit collection to City boundaries. Consequently, figures which quantify the total waste load of the City and County of Denver in 1980 are not available. In 1976, a study of the Denver Region reported the waste generation rates shown in Table 6. It is

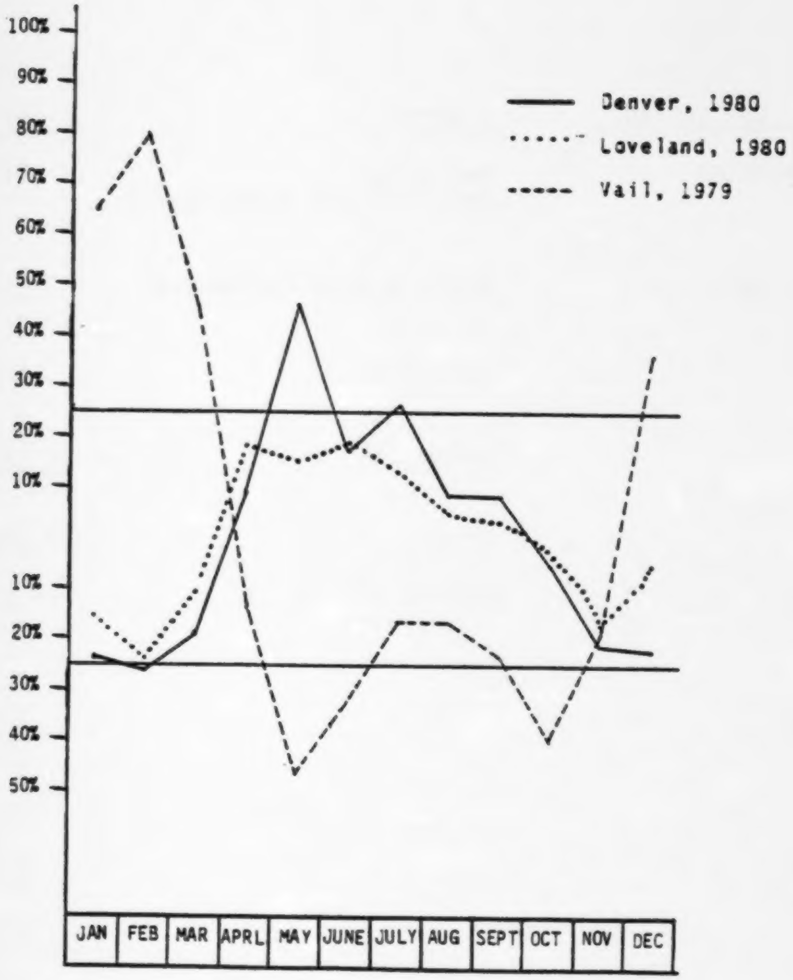
TABLE 5
RESIDENTIAL SOLID WASTE IN THE CITY AND COUNTY OF DENVER
(Tons Per Year)

Collection Agent	Number of Housing Units Per Residence	1978		1979		1980	
		Tons	Percentage	Tons	Percentage	Tons	Percentage
City	Seven or less	166,722	63%	197,981	63%	196,305	63%
Private	Eight or greater	97,099	37%	115,304	37%	115,290*	37%*
TOTAL		263,821	100%	313,285	100%	311,585*	100%

* Only the tonnage collected by the City in 1980 is actually known. It was assumed that the proportions remained consistent from previous years so these two figures were extrapolated on that basis.

Source: City and County of Denver.

FIGURE 4
SEASONAL VARIATION OF THREE COMMUNITIES' WASTE STREAMS



Source: Fred C. Hart Associates, Inc.

TABLE 6

DENVER COUNTY WASTE GENERATION
(In Tons Per Day - TPD)

Collection	Source	1975	1980
Municipal	Residental (Multiple and Single Unit)	515	536
Private	Multiple Unit Residential	121	315
	Commercial	560	560
	Industrial	178	178
	TOTAL	1,374	1,589
	AVERAGE PER CAPITA (lb./day)	5.1	6.5

Source: Figures compiled by Fred C. Hart Associates.

assumed, that the commercial and industrial waste streams have remained at the same levels. This yields a total waste stream per day of 1,589 tons or 6.5 lbs./person/day.

The City and County of Denver Sanitary Service Division utilizes two different compactor truck models for residential garbage collection. One is the traditional rear loader compactor truck which requires one driver and two loaders who empty garbage cans from alleys. Approximately 70 percent of the waste is collected in this manner at a cost of $54/ton. The second method consists of providing a 3-cubic yard dumpster for every four residences. An automatic side loader compactor truck with one driver can collect the solid waste at a cost of about $27/ton. The remaining 30 percent of the waste tonnage is collected in this manner. When the side loader system is fully implemented, about 60 percent of the households will use this system. The total budget for collection of 196,305 tons of solid waste in 1980 was $7,875,000 at an average cost of slightly over $45/ton.

The solid waste from the City and County of Denver is being disposed of in three landfills: Denver-Arapahoe (also known as "Lowry" landfill) landfill, located in west central Arapahoe County, BFI landfill, located just north of Denver in Adams County, and County Line landfill, located south of Denver in Douglas County. The Denver-Arapahoe sanitary landfill is owned by Denver but managed by a private firm. The other two landfills are privately owned and managed. The landfill operators set the tipping fees. The City is currently charged $5.00/ton of solid waste for disposal but this fee will be raised to $7.00/ton at one or more of the landfills in the near future.

The solid waste management system in Denver is experiencing several problems. Closure of the County Line Landfill and the BFI Landfill are imminent due to exhaustion of their capacities. Approximately 68 of 85 acres at the County Line Landfill have been filled and the remaining area is expected to last only another three to four years. The BFI Landfill is expected to remain open only another 12 months. Although the Lowry sanitary landfill has over 2,000 unfilled acres available for development, use of that landfill is clouded with controversy.

In addition, there are 83 closed disposal sites in the City and County of Denver. According to the Colorado Department of Health these sites must be assessed for methane or leachate production potential and environmental protection requirements.

The City and County of Denver and its surroundings have achieved by far the highest level, variety and potential for resource recovery in the state. Almost all of the recycling organizations listed in Table 4 operate in Denver at one or more locations.

No sampling of solid waste has been performed in the Denver area to determine waste composition. The composition percentages shown in Table 2 are national averages. Several assumptions can be made to qualitatively discuss differences in Denver's waste stream from the national averages. The paper component for Denver is probably greater due to the high number and concentration of business and government offices in the central city area. Waste generation levels for glass, plastic and metal beverage containers are probably also very high. Yard and wood waste levels may be somewhat less due to high urban densities. Construction and demolition waste volumes are currently inflated due to the tremendous construction activity in the city's central business district.

One local recycler estimates that 8,800 tons of newspaper are distributed per month in the Denver area. Of this 17-50 percent is eventually recycled. Present market conditions are characterized by tremendous fluctuations in demand and price for newsprint. A substantial amount of corrugated cardboard is generated by the commercial sector. Many businesses already routinely bale cardboard for recycling. For other paper products (office paper, mixed paper, etc.) the quantities recycled are regarded as proprietary and cannot be estimated at this time.

In 1980 an estimated 57 percent return rate of aluminum cans was achieved. This market is close to saturation. Higher levels of aluminum recycling may be impossible due to the fact that other types of light aluminum (such as baking pans, foil etc.) contain food residues which cause contamination and health problems. As mentioned previously, ferrous metals from industrial sources achieve levels of close to 100 percent recycling. Household sources are steel cans. Markets for steel cans are small or non-existent in the Denver area.

Waste glass is being generated at the rate of about 150 tons per day in Denver. In 1981, Golden Recycle Company, a local buyer-processor of glass, utilized glass at a volume of approximately 30 tons per day, 60-70 percent of which is returned from the Colorado market. There are plans to expand their demand for glass to 100 tons per day in the near future. Conceivably all of this amount could be collected from the Denver area. Golden Recycle Company is presently trying to locate another local flint (clear) glass user to improve the economics of the venture. Another company, Capital Insulation, is attempting to start up a facility in Denver which could process up to 20 tons per day of glass cullet.

Recycling of plastic materials is not now feasible except on a very limited basis. Due to the tremendous number of polymers and the unmeldability of these groups only uncontaminated and segregated plastics can be recycled. Consequently, the greatest possibility for plastics recovery is probably in the form of energy derived from combustion.

Organic solid wastes such as yard and food wastes are not being recycled or reused to any great extent. Therefore until changes occur which make use of these materials more favorable there will continue to be virtually no commercial recycling of these solid waste components.

Loveland. Loveland, Colorado, a city of approximately 30,000, is located in Larimer County in the northern part of Colorado. It is a medium sized city after experiencing an 86 percent increase in population between 1970 and 1980. Although this is a phenomenal rate of growth it is not unusual when compared to other medium and large Front Range Communities such as Greeley (36 percent), Fort Collins (49 percent), Longmont (85 percent), Colorado Springs (59 percent), and Broomfield (186 percent).

The City of Loveland operates a municipal solid waste collection service for all residential customers within the city limits. Three private commercial haulers collect commercial and industrial wastes. The City of Loveland maintains records on the number of loads of compacted waste which are taken to the County landfill. City trucks are weighed for a period of one week four times throughout the year to determine average waste densities and seasonal variation. As a result, figures for residential waste generation and waste load are very accurate.

Table 7 shows current residential waste generation rates. The 1980 residential waste generation rate averaged 2.4 lbs. per person per day. According to previous records and yearly population estimates the waste generation rate has been steadily increasing.

Commercial and industrial wastes, have grown in volume along with population increases and concurrent increased commercial activity. However, records quantifying this growth are not available. Private haulers in the area do not make such figures available. Prior studies have suggested that in cities with populations similar to Loveland's the residential waste stream represents 40 to 60 percent of the total municipal waste stream (i.e., including residential, commercial, and industrial components). Therefore, it was assumed that residential waste represents 50 percent of the waste stream. This assumption suggests that total solid waste generation in the City of Loveland is 73 tons/day for a daily per capita waste generation rate of 4.8 lbs.

Seasonal variation of the residential solid waste stream in Loveland shows a pattern similar to that of Denver but with less variation. Figure 4 illustrates that Loveland's waste stream stays roughly within the 25 percent expected seasonal variation. Again, the low point occurred in February and the high points occurred in April and June.

All of the solid waste generated in and around the City of Loveland is being deposited in the Larimer County Landfill which is located about seven miles north of the city. Loveland owns a 25 percent share in the landfill property which is run by the Larimer County Department of Public Works. Area fill with daily cover is the predominant method of operation though trench fill is used where appropriate. The facility consists of 480 acres of which about 60 acres have been completed. The landfill is expected to have sufficient capacity to remain open for over 20 years.

TABLE 7

REFUSE COLLECTED BY THE CITY OF LOVELAND IN 1980

Month	Tons	Average Tons Per Day
January	960.6	31.0
February	808.3	27.9
March	1,013.6	32.7
April	1,291.9	43.1
May	1,305.1	42.1
June	1,291.9	43.1
July	1,285.3	41.5
August	1,192.5	38.5
September	1,132.9	37.8
October	1,099.8	35.5
November	907.4	30.3
December	1,073.3	34.6
	13,362.6 (Year's Total)	36.5 (Average TPD)

Source: City of Loveland

The Larimer County Landfill also maintains a disposal lagoon for septic tank waste. Approximately 252,000 gallons are accepted each week. Several groundwater monitoring wells have been drilled in and around the landfill area and as yet have shown no groundwater contamination. In terms of cover requirements and other regulations the landfill is "usually in compliance" with the State Health Department. No major or minor improvements in the landfilling operation are required or planned.

Solid waste loads are not weighed at the landfill as no scales have been installed; instead, a fee schedule for various vehicles has been developed. Commercial compactor trucks pay for their loads on the basis of volume at the rate of \$1.25/yd.^{3}. Commercial haulers and frequent users of the landfill purchase "dump tickets". The gateman punches out the amount owed at the entrance to the landfill.

The Supervisor of the City Refuse Collection Department in Loveland reports that collection vehicles travel an average of 31 miles round trip per route at a cost of approximately \$1.89 per mile. The Refuse Department Budget averages \$29.44 per ton of solid waste for collection and disposal.

Aside from the local grocery stores which collect aluminum cans, there are two other recycling organizations in Loveland. Both use paper products. One firm functions as a broker for newsprint, cardboard, high-grade office papers, and computer paper and cards. Volumes handled were not available. The other firm collects only newsprint, primarily through volunteer and youth group participation. This firm manufactures cellulose insulation. According to their representative, the collection system is just being organized in Loveland and volumes are not yet known.

Overall, the solid waste system appears to be functioning well. Haul distance to the landfill is reasonable and the residents of Loveland are not disturbed by visual impacts, traffic congestion, litter, or odors from the landfill. The system is among the best in the State.

Montrose. Montrose, a town of approximately 9,000, is located on an arid, flat plain near the Gunnison River. The town is surrounded by federally-owned BLM, Forest Service and National Park Service Lands. The area's economy is based on government, agriculture, livestock, mining and services. Montrose does not undergo significant population fluctuations and has grown in population 34 percent in the past 10 years.

The City of Montrose operates a municipal garbage collection service for residential and commercial customers within the city limits. The city does not keep precise records of volumes of solid waste deposited in the landfill. However, volume records were available for the first five months of 1981 and are presented in Table 8. Extrapolating from these data, a conservative estimate of the tonnage can be obtained. This works out to be almost 10,000 tons per year or 27 tons of solid waste per day. The per capita waste generation rate appears to be approximately 6.2 pounds daily. This is a higher rate than that calculated for the City of Loveland but lower than the Denver waste generation rate.

The County of Montrose operates a garbage collection service in the unincorporated areas of the county by maintaining dumpsters. The county will discontinue this service in 1982 and collection will be taken over by private haulers. Private commercial haulers do some commercial collections from the large businesses in the town and county.

All of the solid waste generated in and around the town of Montrose is being deposited in a county-owned landfill in the eastern part of the county. The actual landfill operation is conducted by a private operator for a three year contract period. Commercial compactor trucks, city trucks, and county trucks pay for their loads at the rate of $1.50/yd.^{3}. Other users pay no fee.

Montrose has no recycling outlets except local grocery stores which collect aluminum cans.

The responsibility for solid waste management in the town of Montrose is shared by several governmental offices which do not appear to have a data management system with which to assess and coordinate management activities. No

TABLE 8

MONTROSE TOTAL WASTE GENERATION (1981)

Month	Actual yd.^{3}	
January	3,072	
February	3,069	
March	3,237	Average 3,329
April	3,036	
May	4,233	
June	3,329	
July	3,329	
August	3,329	Estimated from
September	3,329	January - May
October	3,329	data.*
November	3,329	
December	3,329	
TOTAL	39,950 yd.^{3}	
	x .25 tons/yd^3	
	= 9,988 Tons per Year	
	= 27 Tons per Day, average	

* Estimated by FCHA from January - May data as no data was available beyond May.

Source: City of Montrose

centralized information is kept which estimates the landfill waste volume, acreage, landfill capacity, etc. This situation is, however, very typical of smaller communities due to limited resources and low solid waste management priority.

Vail. Vail is located in the Gore Range of the Rocky Mountains in central Colorado. Vail is a major, internationally-known ski resort and an increasingly popular summer resort. As such, the area experiences extreme seasonal population fluctuations. A large portion of the local-employee population resides elsewhere and commutes to Vail daily. Therefore, the permanent, year-round population of the Town of Vail in 1980 was only about 2,300 persons. Officials from the Town of Vail estimate that there are 4,000 residents during the winter (December-March) and summer months (July-September) but only about 350 in the spring and fall. In addition, there are an estimated 20,000 tourists at any time during the winter, 15,000 in summer and 9,000 in spring and fall. Because of it's relative proximity to the Denver area, there are also a significant number of day users of the ski area.

The economy of Vail is solely tourist based. Tourism, in turn, is affected by the national economy and the weather. Although the Town of Vail has a very small resident population, it actually has an incongruously large tax base because of the size of the visitor population and expensive real estate values. There is no industrial activity in the Gore Valley.

The State of Colorado has a number of resorts which experience similar population fluctuations and face similar solid waste issues. Some of these are Estes Park, Telluride, Aspen, Dillon, Keystone, Durango, and Steamboat Springs.

Table 9 presents tonnages hauled during a twelve month period in 1978-1979. Essentially, all of the waste generated in Vail/Gore Valley is hauled to the County landfill by one private hauler so that the quantities are specific to the area and well substantiated.

The seasonal highs and lows of the waste load are almost exactly opposite of the "typical" case (see Figure 4). The quantities in 1979 varied from a low in May of 9.8 tons per day to a high in February of 32.8 tons per day. As there

TABLE 9

SOLID WASTE GENERATION IN VAIL, COLORADO

Month		Tons Per Day		Tons Per Month
December, 1978		24.9		772.2
January, 1979		30.1		933.1
February		32.8		918.4
March		26.6		825.8
April		15.7		471.6
May		9.8		303.5
June		12.4		372.6
July		15.1		466.6
August		15.1		466.6
September		14.0		420.0
October		11.0		370.5
November		12.2		364.5
	AVERAGE	18.2	TOTAL	6,685.4

Source: Franklin Associates, Ltd.
Resource Recovery Feasibility Analysis for Eagle County, Colorado, July, 1980

is very little yard waste and no industrial activity in the area, the waste load figures in Table 9 represents a waste stream composed only of residential and commercial waste. The solid waste quantities for Eagle County include high amounts of construction wastes. Because of the way in which estimates for the Vail area were obtained, it is not possible to determine what, if any, proportion of the Vail waste stream is comprised of construction waste. The magnitude of the tonnage figures vary directly with the population-tourist load at any given time. Using the population figures provided by the Town of Vail it appears that the average daily per capita waste generation rate is between 2 and 3 lbs. with an average of about 2.8 lbs./person/day. Solid waste composition in Vail/Gore Valley may be quite different from national estimates although this cannot be substantiated with actual data.

Management of solid waste for the Town of Vail presents some unique problems. Most obvious, is the tremendous variation in the amount of solid waste generated in the area. Variations of over 200 percent in monthly waste loads require a high degree of flexibility in terms of equipment use, personnel and organization of collection routes.

The solid waste from the Vail area is deposited in the Eagle County landfill. The landfill is located approximately twenty-two miles away near Wolcott, Colorado. A long haul distance such as this presents problems of time and increased costs especially considering that the final three-quarters of a mile of the route is a winding, unpaved mountain road. Access is most difficult during the winter when the waste volume is at the highest levels.

Landfills located at high altitudes experience problems with winter filling due to the incidence and severity of frost action at the ground surface which complicates the process of obtaining cover material, causes equipment freezing problems, high winds, drifting snows, etc.

In addition, the limit of the present landfill's capacity will be reached in two to three years. Adjacent land is probably available for additional landfill space so the situation is not yet critical. The average cost of solid wastes deposited at the Eagle County landfill in 1979 was $6.84/ton.

Aluminum cans and returnable glass beverage containers are the only routinely recycled solid waste components in the Vail area. (Even so, it is estimated that there are 110 tons per year of unrecovered aluminum cans in the waste stream.) These items are handled through local grocery stores. Because these are the only recovery systems in place, recycling potential at the present is low. Difficulties with transportation and the relatively small waste stream are not conducive to economically favorable recycling under current market conditions.

In 1978, local school board officials in Eagle County applied for a grant to study the possibility of a waste-to-energy facility in Eagle County. A grant was awarded under the Urban Policy Program on the basis of projected severe waste disposal problems and the potential presence of a suitable energy consumer.

A resource recovery feasibility study was conducted in Eagle County from August, 1979 until July, 1981 under the EPA Resource Recovery Project Development Assistance Program (a part of the Urban Policy Program). As the study proceeded, the major energy consumer candidate had to be dropped from further consideration. To compensate, district heating of multi-unit housing was discussed with local resort developers with encouraging results. The planning proceeded to the preliminary stages of construction negotiations. Unfortunately, an unsuccessful winter ski season created financial and investment obstacles to commitments of capital. Also, traditional prejudices to garbage-related facilities began to affect the serious pursuit of such options. Because the population fluctuates so dramatically and rapidly it is extremely difficult to generate public interest and support for a solution which requires a relatively long-term commitment. Due to these and other constraints the study concluded that the economics of the project were not currently favorable although the potential for future development exists. The outcome of the study process has been that the same solid waste management problems exist and no viable alternatives have yet been identified.

Summary Evaluation of the Representative Communities. Study and evaluation of the solid waste management systems within the four representative communities results in the following general conclusions about the current solid waste management and resource recovery outlook in the state:

- landfilling is currently the primary statewide solid waste disposal option;
- the communities which were examined within this analysis, while not confronted by immediate solid waste management emergencies, have planning and operational problems which are representative of the problems confronting the majority of Colorado communities;
- resource recovery, in the form of recycling, is being practiced to a limited extent. Indications are that recycling efforts will expand and potential exists for waste-to-energy systems.
- all the recycled materials markets within the State are located in Denver; and
- markets which would encourage resource recovery are generally lacking.

These and other conditions greatly effect the consideration and viability of resource recovery as a waste management option.

III. CONSIDERATION OF THE RESOURCE RECOVERY OPTION

Consideration of Resource Recovery as a Viable Option

As discussed previously and as experience in Europe, Japan and other parts of the United States has demonstrated, increasing landfilling costs and associated environmental and economic trends indicate that there is a natural progression toward consideration of resource recovery as an additional solid waste management tool. Feasibility of resource recovery, however, can only be determined on a case-by-case basis. The environment which would most contribute to resource recovery consideration is shown in Figure 5.

Evaluation of resource recovery can be undertaken by the private sector, public sector, non-profit organizations, or combinations of the above. The process of evaluation requires certain information including:

- the efficiency, effectiveness, cost and current and future constraints of solid waste management options;
- the basic legal and institutional structure confronting implementation;
- the availability of funds (current and projected) for waste management;
- the degree of social and political acceptability and public support for each management option;
- the levels of risk and uncertainty associated with the options; and
- other factors which cannot be placed into monetary or numeric terms.

This information would ideally be considered within the context of priorities, goals, resources and constraints of the solid waste management structure in each specific situation. The first step in considering resource recovery is the

FIGURE 5

ENVIRONMENT CONDUCIVE TO RESOURCE RECOVERY

- Amount of wastes generated are significant (communities in which populations are relatively concentrated)
- Few landfills exist or are far from the point of waste generation
- Landfill tipping fees are high
- Energy costs are high
- Industry raw material costs are high
- Environmental standards are strict and enforced
- Land is scarce and there is pressure to develop land for more profitable uses
- No or few other disposal alternatives exist

Source U.S. Conference of Mayors

the recognition of solid waste problems which either currently exist or are likely to occur in the future. The necessary information to make this recognition is rarely readily available to appropriate decision makers. Consequently, resource recovery is not being adequately considered in the decision-making framework and process.

Factors Affecting Resource Recovery Feasibility.

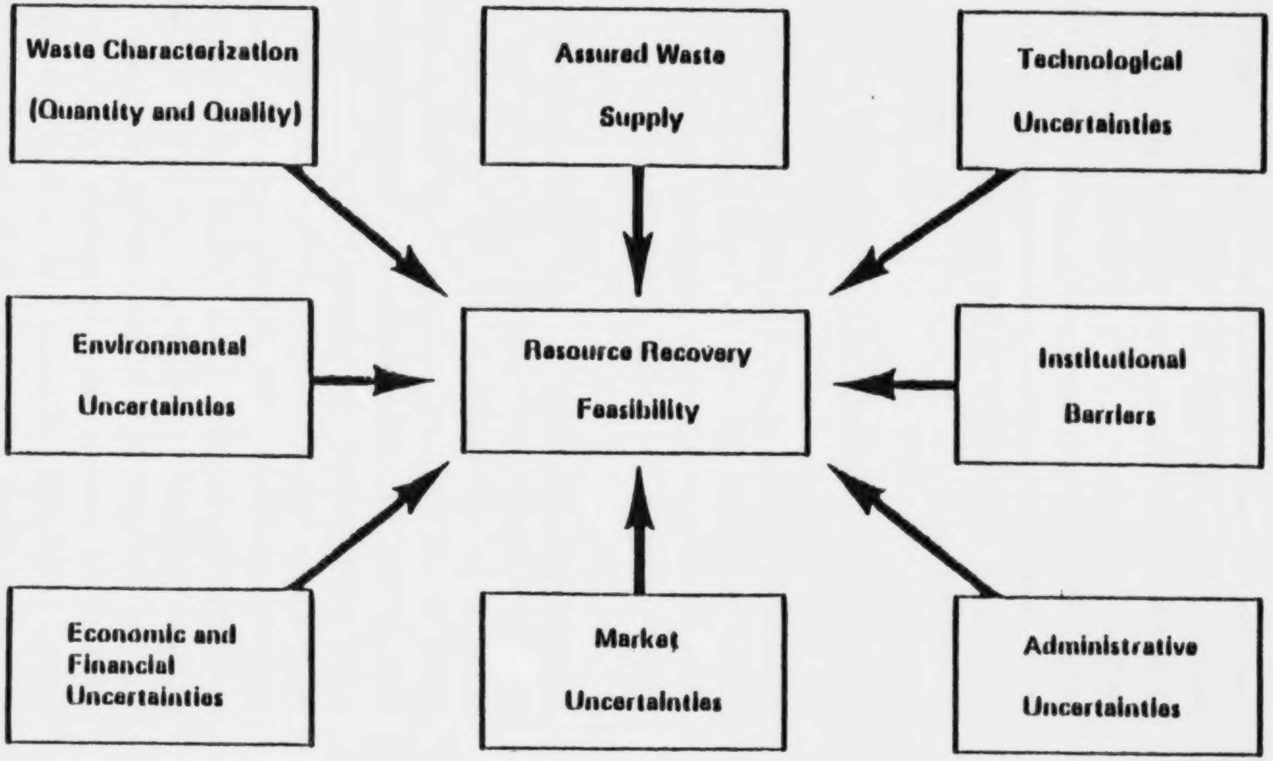
Figure 6 presents a number of factors which affect the feasibility of resource recovery options. Each factor must be evaluated within the context of a specific solid waste system during the planning phase of each potential project. To expedite this analysis the Environmental Protection Agency has prepared a comprehensive Resource Recovery Planning Model which guides planners through the factors and identifies the go/no-go decision points. The factors are discussed in a general way below, with examples of Colorado situations where this information is available.

- **Waste Characterization and Availability.** In order to estimate the potential amount of materials available for recycling and/or conversion to energy, certain basic information on the quantity and quality of wastes must be obtained. This basic information allows the projection of potential revenues and identification of potential markets.

- **Assured Waste Supply.** Private commercial haulers of solid waste choose the disposal site they patronize based on the lowest cost combination of disposal fees (tipping fees) and transportation (i.e. round trip travel distance). Goverment collection agencies, on the other hand, may consider other factors such as the fuel requirements of an incineration facility. Waste-to-energy facilities which depend on wastes collected by private haulers must be assured of receiving an amount of waste adequate to permit the optional utilization of the facility. Where private haulers have chosen not to use a waste-to-energy facility based on cost considerations, governing agencies have, in some cases, promulgated waste flow control ordinances. These ordinances require that all wastes collected within a certain jurisdiction be delivered to a waste-to-energy facility. Unfortunately, such ordinances can substantially disrupt any

FIGURE 6

FACTORS AFFECTING RESOURCE RECOVERY IMPLEMENTATION


Waste Characterization (Quantity and Quality)
Assured Waste Supply
Technological Uncertainties
Environmental Uncertainties
Resource Recovery Feasibility
Institutional Barriers
Economic and Financial Uncertainties
Market Uncertainties
Administrative Uncertainties

Source: Fred C. Hart Associates

operating or planned source separation efforts. This issue remains untested and unresolved in Colorado. Preliminary examination of the legality of waste control ordinances in Eagle County suggested that under Colorado statutes, the County could not regulate the waste stream flow within its limits. Further analysis has qualified that conclusion somewhat by suggesting that the County, as the owner or joint owner of a waste-to-energy facility, could control waste flow through ordinances. Legal powers of municipalities in Colorado may allow cities to pass such ordinances. However, a recent Supreme Court ruling concerning the City of Boulder questions the extent of legal powers of cities in Colorado.

- **Technological Uncertainties.** Many of the waste-to-energy technologies are still being developed. Incineration with heat recovery appears to be the most reliable and adaptable waste conversion technology. While source separation may not face the myriad of technological problems of waste-to-energy facilities, equipment selection and operation and maintenance problems are often encountered.

- **Institutional Barriers.** Institutional barriers can be thought of as non-technological, non-economic considerations arising from the laws, policies or relationships of and among organizations, governmental entities and other institutions. For example, freight rate discrimination is one important example of an institutional constraint. Freight rates have favored the transportation of virgin goods over recycled materials, a situation which affects the economic viability of resource recovery activities. In October, 1981, the Interstate Commerce Commission ordered railroads to roll back rates and refund excessive charges on many recyclable commodities. The order followed 10 years of litigation by the National Association of Recycling Industries (NARI) and provides for establishment of maximum rates on a commodity-by-commodity basis. Railroads contended that a single composite base rate for all recyclable items be used and that escalations for volume and mileage then be added. The result of this order is that rate rollbacks and refunds will be applied primarily to the transport of all non-ferrous metals and, to some extent, to the transport of wastepaper, textile waste, scrap rubber and reclaimed rubber, scrap plastics, and cullet.

Scrap iron and steel are not included in these provisions. For some commodities, the railroad profit levels will be reduced by 20 percent to 50 percent. NARI is presently attempting to eliminate discriminatory rates for wastepaper.

- **Administrative/Jurisdictional Uncertainties.** If a resource recovery system involves a number of jurisdictions, and/or is involved in a complex arrangement between the public and private sectors, the continued involvement of all parties is uncertain. Although contracts and agreements may be signed among municipalities and firms, the possibility of a jurisdiction pulling out from the agreement, or other associated administrative problems, are real possibilities. One method which can be used to implement a waste-to-energy system in an area which includes several governmental jurisdiction is the formation of a solid waste district which is permitted under Colorado law. However, no solid waste disposal districts have yet been formed in the State. Presently, there is an effort in Yuma County, Colorado to establish a solid waste disposal district. County and municipal officials in Yuma County have, however, found problems with this statute since districts can be formed only within unincorporated areas. This is somewhat impractical because waste generation is concentrated in the incorporated areas. Also, the statute limits taxing to 1/2 mill, an amount that is thought to be too small. An effort is underway to determine if a solid waste disposal district can be set up under other statutes for special purpose districts or to change the Colorado law.

- **Market Uncertainties.** A resource recovery operation cannot be successful without the existence of relatively stable and secure buyers (markets) of the recovered materials or energy. Markets for many recovered materials in Colorado are relatively weak due to geographic isolation from national markets and lack of major regional industrial development. It is often difficult to achieve negotiation of and agreement on long-term contracts specifying the quantity, quality and price of recovered resources. The marketing of recovered resources is subject to price and market capacity fluctuations which can prove to be disastrous. Eco-Cycle, in Boulder, has developed contacts with buyers of its key products (corrugated cardboard, paper, and glass) that appear to insure adequate demand for those products. Eco-Cycle states it can sell all it can produce without fear of affecting the market (i.e., without having to lower the price). Recycle Something, in Fort Collins, is a smaller volume operation than Eco-Cycle. Newspaper is the mainstay of Recycle Something's program in terms of amounts processed and income generated. The demand for newsprint is highly seasonal and the market is distant. These factors at times combine to affect Recycle Something's revenues by a factor of three, causing severe economic hardship and a non-viable operation. With respect to energy recovery, it is often stated that consumers of energy products are readily available, however, a 1982 study by Fred C. Hart Associates performed for Larimer County, indicated that no suitable market for steam existed for a proposed waste-to-energy facility.

o **Economic Uncertainties.** The feasibility of a resource recovery operation is dependent upon projections of costs and revenues. In some cities, projections have been based on optimistic or inaccurate information which lead to unsuccessful implementation. Costs and revenues are greatly affected by current economic conditions. For example, negotiations with private developers for partial financing of a waste-to-energy facility in Eagle County were terminated by changing economic conditions due to a snow drought. A recurring problem in waste-to-energy feasibility assessments in Colorado and elsewhere is the lack of a clear definition and interpretation of the price a public utility is required to pay for electrical energy purchased from small generators according to the Public Utilities Regulatory Policy Act (PURPA). In cases of marginal feasibility this factor may tip the balance one way or another. The State Public Utilities Commission has implemented a program designed to clarify this issue. A more definitive answer may be available in the later part of 1982.

o **Environmental Uncertainties.** The environmental and health aspects of most waste-to-energy systems are only currently being defined. It is uncertain if some of these technologies can meet existing environmental rules and regulations without very costly process modifications or control procedures. Of special significance in Colorado is the air pollution regulatory framework. An energy recovery incinerator project currently being considered by the City and County of Denver has identified this area as one of the major factors affecting project feasibility. Appendix 3 is a discussion of environmental compliance which was originally prepared for a Boulder waste-to-energy feasibility study performed by Fred C. Hart Associates in 1981.

All of these factors affecting resource recovery feasibility create a planning and implementation atmosphere of relatively high risk and uncertainty. Reduction in risk and uncertainty should be a major public sector priority if it is determined that encouragement of resource recovery is a desirable goal.

Figure 7 identifies and ranks various types of impediments affecting the success of operating waste-to-energy operations, based upon a survey taken in 1978. Any case-specific feasibility study must closely examine and analyze each of these impediments early in the planning process.

Resource Recovery Option Comparison

There are a variety of resource recovery options which could be evaluated as alternatives to landfilling. These range from low technology/high labor-intensive efforts to sophisticated technological systems. Options which are considered to be the most viable alternatives in the near-term include:

- source separation recycling; and
- incineration with heat recovery.

Additionally, a combination of the above options must be considered. A recent comprehensive analysis of costs, performance, and environmental acceptability and marketability (see Table 10 for criteria) of the resource recovery options in Table 11 by the Environmental Protection Agency rated source separation recycling and incineration with heat recovery the highest. Experience within Colorado confirms these findings. Each option is further discussed below.

FIGURE 7

RELATIVE SIGNFIICANCE OF IDENTIFIED IMPEDIMENTS TO WASTE-TO-ENERGY FACILITIES*

- Inability to compete with landfill disposal fees
- Technological difficulties and limited experience
- Unrealized projections of revenue from product sales
- Government intervention in market pricing and resource allocations
- Overdesign of plant capacity
- Underestimation of initial capital costs
- Environmental regulations
- Fragmentation/conflicts of governmental authorities
- Underestimation of O & M costs
- Overestimation of materials recovery
- Overestimation of available waste quantities
- Pricing energy below market replacement value
- Public opposition to siting
- Local politics and labor-management problems

* Ranked from most significant to least significant from a 1978 EPA/Mathtech survey

Source: EPA

TABLE 10

RESOURCE RECOVERY SYSTEM RATING CRITERIA

I. PERFORMANCE

A. Reliability: System and components proven to perform dependably and with minimum down-time.

Rating	Description
High	Proven performance with high reliability
Medium	Adequate performance with adequate reliability
Unacceptable	Inadequate performance with inconsistent reliability

B. Degree of Waste Volume Reduction

Rating	Description
High	>60%
Medium	30-59%
Low	0-29%

C. Freedom from Maintenance/Simplicity

Rating	Description
High	Simple; minimal skills required for operation; few or no moving parts
Medium	Moderate; intermediate in mechanical complexity; operation requires some degree of skill and/or training
Low	Complex; involves sophisticated mechanical equipment; skilled and trained operators required

II. ENVIRONMENTAL ACCEPTABILITY

A. Meets all minimum standards for air, noise, water and land pollution

Rating	Description
Acceptable	Complies with minimum standards
Unacceptable	Does not meet standards

B. Maximizes resource recovery within technological limits

Rating	Description
High	Recovers maximum number of resources; > 60% of waste
Medium	Recovers moderate number of resources; 30-59% of waste
Low	Recovers few resources; <29% of waste stream

III. MARKETABILITY OF RECOVERED PRODUCT(S)

Rating	Description
High	Product(s) have ready markets
Medium	Product(s) are somewhat marketable, but prices subject to cyclical swings
Low	Product(s) difficult to market or have very low value

Source: U.S. Environmental Protection Agency

TABLE 11

RESOURCE RECOVERY SYSTEM RATING (100 TPD System)

	Reliability	Waste Volume Reduction	Freedom from Maintenance; i.e., Simplicity	Environmental Standards	Resource Recovery	Marketability of Product(s)	Net Cost/Ton*
Ferrous Recovery	Medium	Medium	Low	Acceptable	Low	Low	$15.38
Compost	Medium	Medium	Low	Acceptable	Medium	Low	26.70
Compost with Ferrous Recovery	Medium	High	Low	Acceptable	High	Low	26.05
RDF with Ferrous Recovery	Medium	High	Low	Acceptable**	High	Medium	13.61
Incineration with Energy Recovery	High	High	Medium	Acceptable**	High	High	11.68
Incineration with Ferrous and Energy Recovery	Medium	High	Low	Acceptable**	High	Medium	11.95
Source Separation	Medium	Medium	High	Acceptable	Medium	Medium	8.16

---

* Cost of operating system minus revenues plus disposal of non-recovered material (costs in 1978 dollars).

** May require external air pollution control equipment.

Source Separation. The basic requirements of most source separation systems consist of:

- Preparation and segregation of material(s) - individuals and businesses segregate and prepare recyclables.
- Materials collection - materials are collected at the source (curbside pick- up) or brought to a central facility by recycling patrons.
- Materials processing - each material is processed and stored according to market specifications.
- Materials marketing - secondary materials are transported to secondary material brokers or industrial consumers.

The materials targeted for recovery, the preparation and processing requirements, method of collection, and materials marketing are all dependent upon local conditions such as:

- Markets
- Population
- Investment capital, and
- Public support.

Most source separation programs employ one or more of the following concepts:

1. **Curbside collection.** Participants place recyclable materials in a prearranged manner and at a prearranged time for collection. Curbside collection may be multi-material (typically newspaper, glass, mixed metals) or single material (usually newspaper or yard waste).

A major advantage is that curbside programs usually produce the greatest public participation and diversion of materials from landfill disposal.

Several disadvantages exist because of the collection vehicle and labor requirements. Curbside collection is typically the most expensive approach. Actual cash requirements are dependent upon program design, accounting, and participation. Because of the larger volumes, materials processing, such as baling and ferrous metal separation, is appropriate. This requires a greater capital commitment but also yields higher market prices for materials.

2. **Buy-back centers**: As the name implies, buy-back centers purchase discards from the recycling patron. The centers typically purchase only the high grade materials such as aluminum and certain grades of papers. Other materials such as glass, bi-metal cans, and waste oil may be accepted as donations.

A primary advantage is that buy-back centers target materials, such as aluminum, which yield a high market value per pound. The centers purchase small quantities of materials from individual recycling patrons and make a profit by marketing bulk shipments of upgraded (sorted and/or prepared) materials. Buy-back centers are generally the most capable of financial self-sufficiency due to the limited range of materials purchased and their ability to regulate volume by pricing.

Buy-back centers require up front cash to operate and ten to 60 days may be required to provide a return. The recycling center must have capital-intensive site improvements and equipment to handle significant volumes of materials.

3. **Donation Centers.** Donation centers accept materials solely on a donation basis and are typically small volume operations with minimal materials processing. They can be single or multi-material and may be manned (usually utilizies voluntary labor) or unmanned centers.

Donation centers can be established with minimal initial investment and are appropriate for small communities which cannot justify high capital investments. On the other hand, donation centers generally recover a very small percentage of the recyclable materials that are available in the waste stream. Unmanned centers often develop problems with trash being dumped into recycle bins resulting in high contamination levels.

4. **Integrated Approach.** Integration of source separation programs with conventional garbage collection and disposal can improve a program's chance for success.

This approach assures that components of the waste stream are recovered in the most efficient and cost-effective manner. Highly marketable materials are separated and sold while low demand items are coverted to energy through incineration. Also transfer stations and landfills are ideal locations for placement of donation centers and may be appropriate for buy-back centers.

The main disadvantages to this approach are the lack of well designed collection equipment for separated materials and resistance of personnel to the increased complexity of collection duties.

Incineration with Energy Recovery. The basic requirements of waste-to-energy systems consist of:

- Collection of solid waste - collection is performed by either municipal or private refuse collectors just as in a typical landfill disposal system.
- Delivery of solid waste to the incinerator facility - waste is delivered to the facility and used immediately or stored (on the order of 1-3 days) as required by consumer energy-use patterns.
- Solid waste processing - the extent of processing depends upon the incinerator technology chosen. Processing may consist of removing bulky or hazardous items, mixing of various waste streams or shredding of wastes to achieve optimal heat energy.

Two important factors are necessary for the success of a waste-to-energy facility: 1) the assured supply of an adequate volume of solid waste and 2) consumer(s) willing to purchase the energy at predetermined rates and prices.

Incineration with heat recovery is advantageous because it utilizes otherwise "lost" resources. Moreover, incineration reduces solid waste volumes entering the landfill by 80 to 90 percent and reduces waste tonnage by 50 to 70 percent. Finally, revenues from energy sales help offset solid waste disposal costs.

One disadvantage of incineration is that in many areas, tipping fees charged by waste-to-energy facilities cannot compete with lower landfill charges. In addition, waste flow control ordinances may be required to assure that waste will be delivered to the incinerator. Incinerator air emissions contain heavy metals and particulates, which makes siting difficult in most areas. Furthermore, the revenues received for the produced energy may be too low to offset cost of its generation.

Waste-to-energy systems can be developed to produce different energy products:

1. **Steam Only** - most waste-to-energy incinerators produce steam as the only energy product. It is sold for heating, cooling and/or process uses.

Advantages: Technologies for producing only steam have had widest application in this country. Steam production provides incinerator efficiencies of 50 to 75 percent.

Disadvantages: Few consumers requiring steam volumes such as generated by waste-to-energy systems exist in Colorado. There are very few industries with process steam needs. Steam generating plants need to be located relatively near (1-2 miles) the steam consumer(s).

2. **Cogeneration** - refers to the generation of electric power from a combustible fuel and the concurrent utilization of "waste" heat from the generating process.

Advantages: Electricity is a relatively easily saleable and transportable product. Since the Federal Public Utilities Regulatory Policy Act (PURPA) requires that electric utilities purchase electricity offered for sale by small generators at the net avoided (marginal) cost to the utility, markets for electricity from waste-to-energy systems are assured.

Disadvantages: Electricity generation dramatically reduces waste-to-energy facility efficiencies to about 25 percent. Electricity generation from waste-to-energy facilities has not yet been used in the United States. Interpretation of PURPA and the term "net avoided cost" has remained relatively unclear to date so potential revenues from electricity sales cannot be dependably predicted.

Combining waste-to-energy incineration with traditional garbage collection and disposal can result in a more efficient solid waste management system for the following reasons:

- Resources that would ordinarily be "lost" in the landfill are retrieved through incineration.
- Incinerator systems significantly reduce landfill space requirements, usually, on the order of 80 to 90 percent. There will still be a need for landfills for incineration residues and wastes which are non-combustible.

Combination of Source Separation and Incineration with Energy Recovery. Combining source separation programs with waste-to-energy incinerator systems is potentially the most cost-effective and environmentally sound solid waste management system. Materials which are relatively easily recycled (considering public convenience, process complexity, market stability and prices) can be selectively removed from the collection system. The incinerator can then be designed to process the remainder of the waste stream. Although no full-scale combined systems currently exist in the U.S., a number of communities with incinerators still have viable recycling programs which have been described as being complementary rather than competing. In general, full-scale recycling systems have been limited to capturing 10 to 20% of the total waste stream and most solid waste experts agree that higher percentages are not likely in the near future. Based on this alone, recycling systems and waste-to-energy systems may be inherently compatible.

The basic requirements of a combined solid waste management system include:

- Separation of solid waste - solid waste is separated into recyclable and nonrecyclable portions by individuals and businesses.
- Collection - the separated solid waste stream portions are collected either with modified conventional collection equipment or transported separately by combining commercial collection of solid waste with one or more of the collection methods mentioned in the source separation section.
- Processing - waste stream portions are delivered to the appropriate facilities and processed as required.

A primary advantage of this combined system is that source separation of recyclable materials reduces capacity requirements for the landfill and the modular incinerator, a situation potentially resulting in reduced total costs. Source separation also removes noncombustibles from the waste stream which can cause maintenance problems in the incinerator. Nonrenewable resources (usually noncombustible) are recovered and renewable resources are salvaged in the form of energy. Solid waste management is more efficient because the waste stream can be managed in response to material and energy market forces. Moreover, in the event that one form of resource recovery option is not economically justified, an alternative system is functioning to replace it. In addition, incineration retrieves resources for which recycling technologies or markets do not exist.

Disadvantages of combined source separation and incineration include possible competition for materials, such as paper and plastic, thereby reducing viability of one or the other or both. Also, combining resource recovery systems increases the complexity and, potentially, the costs of waste collection and processing.

Study of waste-to-energy feasibility in Boulder, Colorado concluded that there is no basic incompatibility between the continued existence of Eco-Cycle, the highest-volume nonprofit recycling group in Colorado, and the existence of a waste-to-energy facility. The report by Fred C. Hart Associates explained that Eco-Cycle, by realizing its projected higher participation level, could cause a smaller resource recovery facility size resulting in potential loss of scale economies and loss of some revenues. However, total waste disposal costs for the County may be lower since the portion of the waste they remove is handled at low cost. At its projected level, Eco-Cycle would remove substantial amounts of combustible material (paper) from the waste stream, but the amount of paper removed would not have a marked impact on the composition of the remaining stream. Removing 38 TPD of paper and 14 TPD of noncombustibles leaves the remaining waste stream 69.5 per cent combustible, reducing the percentage of combustible material in the waste stream by only 0.5 percent.

Table 12 summarizes the issues relating to certain specific factors which may influence consideration and implementation of source separation recycling and incineration with heat recovery. The factors have been identified as major concerns by parties in Colorado who were contacted during the research efforts conducted to complete this study.

TABLE 12

FACTORS AFFECTING SOURCE SEPARATION AND INCINERATION POTENTIAL IN COLORADO

Factors	Source Separation Recycling	Incineration With Energy Recovery
Community Attitudes	o prevailing belief that it is a major contribution to the community	o lack of awareness about waste-to-energy systems
	o commonly thought to be inconvenient (too much work, creates clutter, takes up space around homes and offices)	o public opinion strongly supports renewable energy supplies
	o resistance towards non-profit, government subsidized recycling in some cases	o do not want major facilities near residences
	o scavengers steal curbside materials during high-market periods	
	o do not want storage areas near residences	
Involvement and Education	o potentially involves a large segment of community thereby increasing awareness of conservation, litter, and packaging issues	o public involvement with the system essentially non-existent so the public perceives no change in involvement
	o community involvement is extremely important for success	o requires education to overcome resistance to siting facilities in populated areas
Air Pollution	o could improve air pollution problems through use of fewer natural resources	o potential for new air pollution sources

TABLE 12 (Continued)

FACTORS AFFECTING SOURCE SEPARATION AND INCINERATION POTENTIAL IN COLORADO

Factors	Source Separation Recycling	Incineration With Energy Recovery
Numbers of Jobs Created	o typically very labor-intensive in all phases o subject to labor cutbacks due to materials market fluctuations	o potential to increase the number of jobs, although it can be less labor- intensive than landfilling; important to match personnel to required skills o collection and transportation labor may remain unchanged
Other Demonstrated Effects	o reduces landfill space and/or incinerator volume requirements o potential to reduce waste generation by producing changes in packaging, consumption and disposal patterns due to increased complexity of waste disposal for individuals o benefits incineration facilities by removing noncombustibles from the waste stream	o utilizes materials that are not usually recycled due to lack of technology or lack of markets o coupled with source separation can provide the most efficient use of waste stream
Institutional/Legal Barriers	o strict resource recovery specifications by buyer o freight rates which descriminate against recycled materials o collection system and vehicles not geared to separated materials	o control of waste stream essential yet may not be possible under current laws o air pollution control requirements may be restrictive

TABLE 12 (Continued)

FACTORS AFFECTING SOURCE SEPARATION AND INCINERATION POTENTIAL IN COLORADO

Factors	Source Separation Recycling	Incineration With Energy Recovery
Institutional/Legal	o subsidized recycling competing for limited markets in some instances with private enterprise o flow control laws may eliminate or severely restrict materials going to recycle centers	o difficult to finance in many cases due to high capital costs o jurisdictional problems o high risk of implementation
Nuisance Conditions	o collection points such as curbsides, drop-off centers, processing and storage centers may be unsightly o improperly contained and prepared recyclable materials can cause litter, aesthetic and vector problems	o may increase truck traffic, congestion in vicinity of incinerator o potential for garbage processing facility to be located in residential, commercial areas

IV. COMPARISON OF LANDFILL AND RESOURCE RECOVERY OPTIONS

Rationale and Basis for Analysis

If the incorporation of resource recovery options in solid waste management is to increase, its costs, benefits and uncertainties must be quantified. In this regard, four major categories of benefits and costs can be discussed. These include:

- production of energy from the conversion of wastes;
- energy savings of using recycled materials compared to the use of virgin materials;
- space saved at landfills by diverting wastes from this destination; and
- costs of landfill disposal versus resource recovery.

These categories are quantified for each of the four representative communities. As a basis for analysis, resource recovery potential for each community has been estimated. These scenarios have been developed through consideration of such factors as:

- factors affecting markets and market potential;
- existence and severity of solid waste management problems; and
- characteristics of the community.

These scenarios do not describe current resource recovery activity, nor do they describe what is necessarily likely to happen in the future. Rather, they attempt to describe short-term, maximum feasible resource recovery levels assuming near-optimal conditions of currently existing markets and institutions.

While the scenarios provide useful information for comparative purposes, it is the concepts of analysis which are more important in this and other applications. The evaluative concepts are discussed below.

Resource Recovery as a Partial Solution to Both Solid Waste and Energy Problems

Resource recovery can result in substantial energy savings in addition to reducing solid waste management problems. Energy benefits result from two processes:

- the production of energy through conversion of the waste supply; and
- energy savings through recycling as an alternative to production and processing of virgin raw materials.

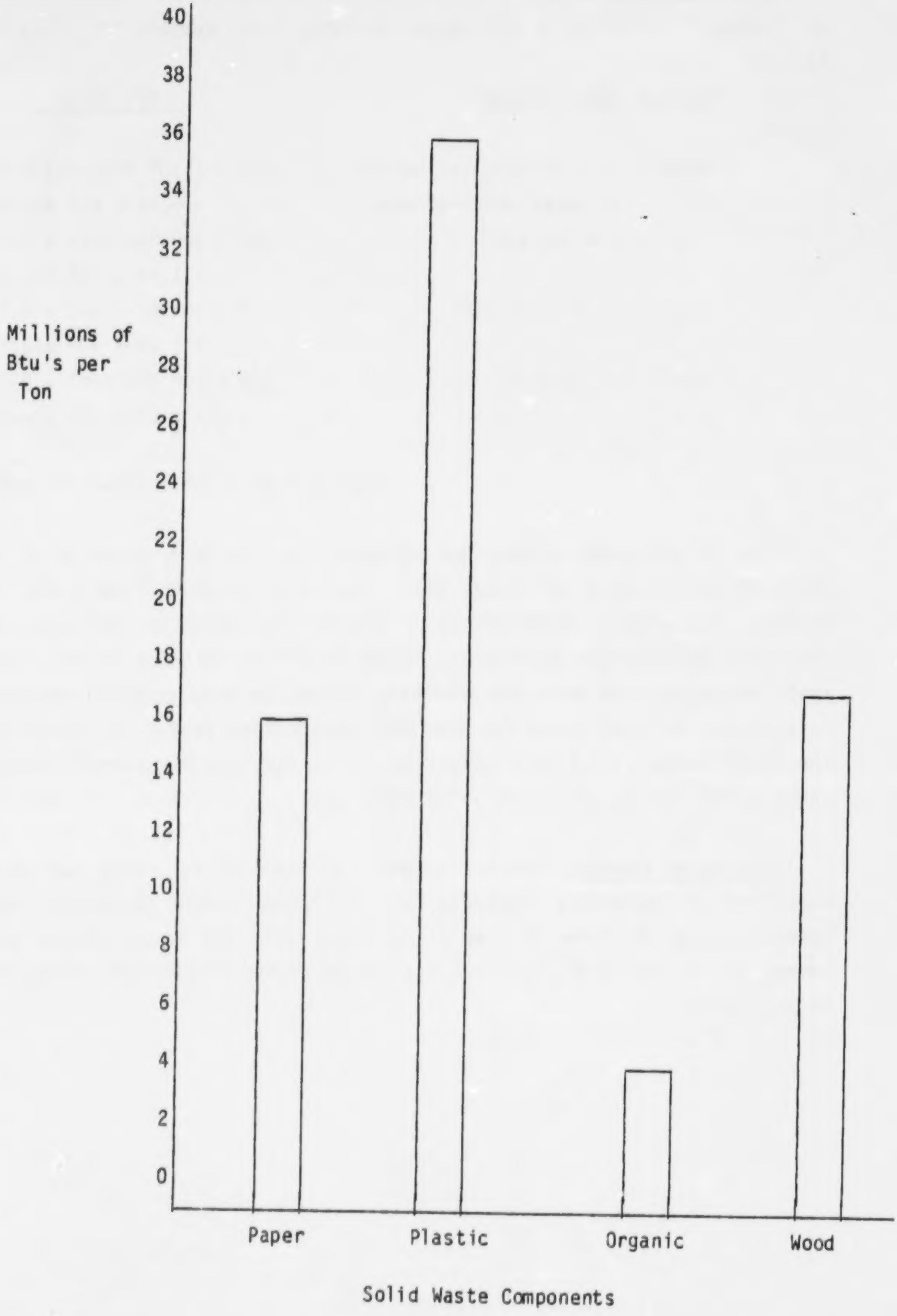
The first benefit is directly realized by the local community, while the second is of primary benefit from a national or regional perspective. The calculation of energy benefits for each process is shown below.

Production of Energy. The Btu value of a waste stream is dependent upon waste stream composition. Figure 8 depicts the variation of heat values for the paper, plastic, organic and wood components of a waste stream. These components are usually the most combustible materials found in a typical waste stream in significant quantities. Plastic has by far the highest heat value at 36 million Btu/ton of material. Paper and wood are about equal at 15.5 million Btu/ton and 16 million Btu/ton respectively. By way of comparison, coal has a heating value of approximately 22 million Btu/ton and oil has a heating value of 36 million Btu/ton.

An awareness of the comparative heat values of various waste stream components is a valuable tool in the management of incineration facilities. Knowledgeable operators can selectively utilize specialized waste streams to obtain an optimal operational effect.

FIGURE 8

HEAT VALUE OF SELECTED WASTE STREAM COMPONENTS



Component heat values are also used to determine the composite heat value of "typical" municipal solid waste streams. An example is illustrated as follows:

"Typical Waste Stream"	Btu Value
Paper - 31.9 percent (by weight of total waste stream)	(15.5 x 10^6 Btu/ton) x 0.319 = 4.94 x 10^6 Btu/ton
Plastic - 4 percent:	(36 x 10^6 Btu/ton) x 0.04 = 1.44 x 10^6 Btu/ton
Organics - 34.7 percent:	(4 x 10^6 Btu/ton) x 0.347 = 1.39 x 10^6 Btu/ton
Wood - 3.9 percent:	(16 x 10^6 Btu/ton) x 0.039 = 0.62 x 10^6 Btu/ton

Total = 8.39 x 10^6 Btu/ton = 4,200 Btu/lb.

The calculations produce an estimate for the heat value of a "typical" pound of solid waste of 4,200 Btu. Estimates ranging from 4,000 to 5,000 Btu/lb. are widely utilized as standards in resource recovery reference materials and engineering studies. 4,500 Btu/lb is utilized in this report. If specific composition data are available during the evaluation of options, these data should be substituted for the more generalized data. In situations where the waste stream yields both materials and energy, the Btu content change of the waste stream can be estimated using Table 13.

Saving of Energy. Various attempts at quantifying energy savings through recycling of materials compared to utilizing virgin materials have been conducted. While there is some disagreement over the actual energy quantities saved, the following data are representative of the significant energy impact of recycling.

Reproduced from best available copy.

TABLE 13

BTU AND FUEL SAVINGS ADJUSTMENT FACTORS

5000 BTU/lb

MATERIAL	% Reduction in Waste Stream									
	10	20	30	40	50	60	70	80	90	100
Newspaper	.83	.66	.49	.32	.15					
Corrugated	.34	.68	.52	.36	.20					
High-Grade Paper	.83	.66	.49	.32	.15					
Mixed Paper	.85	.70	.55	.40	.25					
Aluminum Cans										
Ferrous Cans				NO BTU VALUE						
Glass										

5500 BTU/lb

MATERIAL	% Reduction in Waste Stream									
	10	20	30	40	50	60	70	80	90	100
Newspaper	.85	.69	.54	.38						
Corrugated	.85	.71	.56	.42	.27	.13				
High-Grade Paper	.85	.69	.54	.38	.23					
Mixed Paper	.86	.73	.59	.45	.32	.18				

6000 BTU/lb

MATERIAL	% Reduction in Waste Stream									
	10	20	30	40	50	60	70	80	90	100
Newspaper	.86	.72	.58	.43	.29					
Corrugated	.87	.73	.60	.47	.33	.20				
High-Grade Paper	.86	.72	.58	.43	.29	.15				
Mixed Paper	.88	.75	.63	.50	.38	.25	.13			

7000 BTU/lb

MATERIAL	% Reduction in Waste Stream									
	10	20	30	40	50	60	70	80	90	100
Newspaper	.88	.76	.64	.51	.39					
Corrugated	.89	.77	.66	.54	.43	.31	–			
High-Grade Paper	.88	.76	.64	.51	.39	.27	.15			
Mixed Paper	.89	.79	.68	.57	.46	.36	.25	.14		

7500 BTU/lb

MATERIAL	% Reduction in Waste Stream									
	10	20	30	40	50	60	70	80	90	100
Newspaper	.89	.77	.66	.55	.46					
Corrugated	.89	.79	.68	.57	.47	.39	.25			
High-Grade Paper	.89	.77	.66	.55	.46	.32	.22			
Mixed Paper	.90	.80	.70	.60	.50	.40	.30	.20	.10	

To use table, locate the subtable for appropriate baseline BTU value of a specific waste stream. Find the material being separated in the first column. Move across the table to the percent value equal to the percent of material being recovered. Read adjustment factor and multiply BTU value of waste stream by this factor to determine the new BTU value of the waste stream. For example, in a waste stream with 7000 BTU per pound, where corrugated material is 20 percent of the waste stream and 70 percent of that is recovered, the recovered paper represents 14 percent of the waste stream. The adjustment factor for corrugated from the 7000 BTU per pound table is between 0.89 and 0.77. Interpolation yields a factor of 0.84. Thus the remaining waste contains 0.84 x 7000 BTU per pound or 5880 BTU BTU per pound.

Source: EPA, Small-scale and Low-technology Resource Recovery Study, 1979.

Net Energy Savings from the Use of Recycled Materials

	10^6 Btu/Ton		Percent Savings[1]	
	Estimate[2]	Range[3]	Estimate[2]	Range[3]
Ferrous Metals	15.5	11.1-40.3	65	50-74
Aluminum	224	169-281	92	92-97
Copper	94.7	40.3-94.7	85	84-95
Lead	17.5	5.5-17.5	65	56-65
Zinc	39.3	11.8-47.0	60	60-72
Paper/Newspaper	35.5	5.2-35.5	64	23-70
Glass	-	1.3-2.5	-	0-14
Rubber	22.1	22.0-22.1	71	70-71

Data Compiled by JRB Associates.

[1] Realized savings resulting from use of recycled materials as compared with total energy expended in refining new materials.

[2] From the National Association of Recycling Industries.

[3] Estimated range from various sources.

Land Savings Through Landfill Diversion

The compacted in-place density of municipal waste in Colorado is estimated to range from 400 lbs. to 1,200 lbs. per cubic yard (with 700 lbs. per yd.^{3} as an average). The actual density is primarily dependent on the density of the waste as it is brought to the landfill and the degree of compaction provided by the particular landfill equipment utilized. Landfills in Colorado range in depth from 8 to 100 feet or greater with an average depth on the order of 20 feet. Generally landfill facilities in Colorado utilize one of two methods of operation. These methods are termed trench-fill and area-fill. In most trenching operations approximately half of the land available for the landfilling is utilized for actual deposition of waste; area-fill operations utilize on the order of 75 percent of the available land.

The total municipal solid waste stream for Colorado is estimated to be 600 tons per day. Assuming an in-place compaction density of 700 lbs. per yard^3, an average landfill depth of 20 feet, and that approximately twice as much total land is needed for a landfill than the amount of land in/on which waste is deposited, the total area of land that is utilized through landfilling in Colorado is on the order of 385 acres per year. Thus, for every one percent of the waste stream diverted from the landfill, approximately 3.85 acres of surface land is saved per year.

Cost Comparison of Options

The cost-effectiveness of any resource recovery system is a function of six variables: 1) capital costs; 2) operating and maintenance (O&M) costs; 3) collection/transportation costs; 4) revenues received for the recovered materials and energy; 5) tipping fees; and 6) the cost of landfilling, the disposal alternative. These factors are combined in the following way to determine cost-effectiveness:

Cost of Option - Revenues = Required Tipping Fee

An economic analysis of source separation programs is normally done in a slightly different manner than that for incineration with heat recovery. This is due to the fact that source separation is concerned only with specific materials within the waste stream rather than the total waste stream which would be burned in an incinerator. Therefore, economic viability of source separation would be indicated in those situations where revenues for the sale of specific waste materials is greater than the cost of operating the program. A revenue/cost comparison could also include a credit given to the resource recovery alternative for diversion of materials from the landfill. More specifically, a given amount of money would have to be spent to dispose of these wastes in a landfill; since the goal of disposal is still accomplished through resource recovery, this amount of money could be credited to the resource recovery operation as a revenue.

Cost-effectiveness does not mean that the lowest cost alternative would be chosen in every case. For example, government may choose to consider other variables such as providing subsidies and/or incentives to provide a system as a public service. The private sector is most likely to apply cost-effectiveness evaluation and implement the highest profit option. Private sector resource recovery operators, such as a paper recycler, however, will only obtain revenue from the sale of paper. Cost savings at the landfill (due to diversion of waste material) will not be realized by the recycler. Therefore, although paper recycling may be cost-effective when considering total solid waste management system costs, a paper recycling operation may not be profitable.

Collection and transportation costs are typically a very significant portion of overall waste management system costs. In fact, these costs generally account for 75%-90% of the total. High population densities, public resistance to landfill siting and regionalization of landfills have all influenced siting of new landfills at increasingly greater distances from waste sources. Because waste-to-energy facilities tend to be located nearer to population centers (because of relatively small acreage requirements, neccessity to be near industrial energy users, and greater public acceptance of waste-to-energy facilities than landfills) the savings in transportation costs to waste haulers can compensate for higher tipping fees.

Resource Recovery Scenarios

Resource recovery scenarios were developed in order to compare resource recovery options to landfilling. Table 14 presents, for the four communities examined, the estimated amount of solid waste generated each day and the assessed estimate of the maximum practical level of recycling in terms of percentage of the waste stream and tons.

The estimation of the maximum practical percentage of recyclable materials required the use of a number of assumptions and subjective judgements. The process of arriving at these estimations is as follows. First, current and historic levels of recycling during periods of high and low prices were determined as accurately as possible. These figures were provided by local recyclers although in many cases figures were not or could not be reported because data was unavailable or proprietary. When local data were not available, state or nationwide estimates were used. Next, existing recycling

TABLE 14

RECYCLING SCENARIOS

Solid Waste Component	Tons Discarded Per Day				Maximum Practical Percentage Recyclable				Tons Recyclable Per Day			
	Denver	Loveland	Montrose	Vail	Denver	Loveland	Montrose	Vail	Denver	Loveland	Montrose	Vail
Paper												
Newsprint	111	2.6	1.9	1.2	65	25	0	0	72	0.7	0	0
Cardboard	102	2.3	1.7	1.1	65	25	5	0	66	0.6	0.1	0
Other	294	6.8	5.0	3.2	65	25	0	0	191	1.7	0	0
Glass	154	3.5	2.6	1.3	30	15	5	5	46	0.5	0.1	0.1
Metal												
Ferrous	119	2.7	2.0	1.4	5	0	0	0	6	0	0	0
Non-ferrous	21	0.5	0.4	0.3	50	40	20	20	11	0.2	0.1	0.1
Plastic	64	1.5	1.1	0.9	0	0	0	0	0	0	0	0
Yard	286	6.5	4.5	3.6	0	0	0	0	0	0	0	0
Food	265	6.1	4.9	0.9	0	0	0	0	0	0	0	0
Wood	62	1.4	1.1	0.9	0	0	0	0	0	0	0	0
Miscellaneous	111	2.6	1.8	1.2	0	0	0	0	0	0	0	0
TOTALS	1589	36.5	27.0	16.0					392	3.7	0.3	0.2

Source: Fred C. Hart Associates, Inc.

operations and systems were evaluated. Areas with functioning recycling groups have much greater potential for continued and/or expanded activity than areas without these operations. Additionally, the level of development of the recycling operations was assessed. Organizations which process a variety of materials, have one or more methods of collection and which have developed extensive and stable market (buying and selling) networks have a much greater potential for increasing the volume of the recycled materials. Community attitudes and awareness were also taken into account. Factors which were considered indicative of attitudes that affect recycling include the existence or lack of a local volunteer recycling effort, the predominant economic activities of the area and any other information which was available and applicable. Markets were also considered in terms of existence, stability, location and ability to accept greater volumes of materials.

It was then assumed that all of the conditions and characteristics would remain essentially unchanged in the near future. That is, no major market expansions will occur. It was assumed that markets are relatively strong, prices paid are at the upper levels, and that participation is relatively strong. Therefore, the maximum practical percentage recyclable represents an estimate of levels which could be achieved at the present time, under favorable conditions. Changes in governmental influence, local and regional location of secondary material buyers, removal of constraints, willingness to bear risk, etc. could result in substantial market changes, thereby encouraging recycling efforts beyond the estimates provided in Table 14.

Analysis of Scenarios

Energy Savings and Recycling Revenues. Table 15 presents potential energy savings and revenues from recycling the quantities of materials specified in the scenarios. The material and energy values are implicity reflected in the price buyers are willing to pay for these recycled materials.

Revenue estimates are based upon prices quoted by Denver area recyclers as typical of their markets. (Newsprint-$25/ton, cardboard-$40/ton, other paper-$90/ton, glass-$30/ton, ferrous metals-$140/ton, other metals - primarily aluminum-$700/ton).

TABLE 15

POTENTIAL ENERGY SAVINGS AND REVENUES FROM RECYCLING THE MAXIMUM PRACTICAL PERCENTAGE OF SOLID WASTE IN FOUR COMMUNITIES

Community	Maximum Practical Tons Recyclable Per Day	Total Energy Savings (Millions of Btu per Day)	Equivalent to Barrels of Oil/Day	Potential Revenues ($/year)	Revenues Per Ton Recycled ($)
Denver	392	6,935	1,196	11,500,000	80
Loveland	3.7	79	13.1	128,000	95
Montrose	0.3	18	3.1	28,100	256
Vail	0.2	17.1	295	26,600	365

Small communities which are far from the Denver Metro Area such as Montrose and Vail can only be expected to recycle high value materials, the revenues of which can offset high transportation costs. The last column in Table 15 illustrates this factor. By recycling the maximum practical percentage of the waste stream, Denver and Loveland could receive an average of $80-$95/ton whereas Montrose and Vail could receive $256/ton and $365/ton, respectively. The smaller communities could economically recycle only aluminum and perhaps very small amounts of other items locally.

It is difficult to estimate realistic costs for recycling operations. This is due to uncertainties such as:

- the type of source separation facility most appropriate to each community (e.g. a drop-off center essentially gives the recyclable material to a middleman at no cost, while a buy-back center results in a direct cost to the middleman); and
- the importance of transportation costs incurred for delivery of materials on a small scale basis.

On a very general basis, however, costs and revenues can be compared. Few studies exist in the literature which quantify source separation costs and cost estimation methodologies. A study performed in Nottingham, New Hampshire entitled "Economics of a Small Rural Town Recycling System: Implications of a Case Study" was an early attempt at quantifying a system. Appendix 4 is taken directly from the New Hampshire report which presents the framework utilized in Nottingham to develop recycling costs (capital, operating, and transportation costs and revenues).

The Nottingham experience serves as a good model for Colorado communities interested in establishing recycling systems. The level of detail necessary to utilize this model is beyond the scope of this report; however, for illustrative purposes, two source separation systems have been developed and costed (see Tables 16 and 17) for the Colorado representative communities.

TABLE 16

VAIL OR MONTROSE DROP-OFF CENTER COST ANALYSIS

Capital Costs	Cost($)	Life	Amortization Factor (10%)	Annual Cost($)
Equipment				
Containers (2)	6,000	5	0.264	1,584
Miscellaneous	1,000	5	0.264	264
Total	7,000			1,848
Construction and Land				
Building and Land-donated	--	--		0
Site Development	4,000	20	0.117	468
Total	4,000			468
TOTAL CAPITAL COSTS - ANNUALIZED				2,316
Operating Costs				
Labor: 1.5 operators				18,000
Energy				1,000
Maintenance				500
Supplies				500
Site Upkeep				300
Miscellaneous				500
Contract Hauling (24 trips at $200/trip)				4,800
TOTAL OPERATING COSTS - ANNUAL				25,600
TOTAL ANNUALIZED COSTS				27,916

TABLE 17

LOVELAND ALUMINUM BUY-BACK/DROP-OFF COST ANALYSIS

	Cost($)	Life	Amortization Factor (10%)	Annual Cost($)
Capital Costs				
Equipment				
Containers (4)	2,800	5	0.264	739
Skidsteer Loader (w/Forklift Attachment)	10,000	5	0.264	2,640
Flatbed Truck	30,000	5	0.264	7,920
Compactor/Baler	12,000	5	0.264	3,168
Miscellaneous	3,000	5	0.264	792
Total	57,800			15,259
Construction and Land				
Buildings and Land (plus donated)	25,000	20	0.117	2,925
Site Development	10,000	20	0.117	1,170
Total	35,000			4,095
TOTAL CAPITAL COSTS - ANNUALIZED				19,354
Operating Costs				
Labor: 2.5 operators				30,000
Energy				10,000
Maintenance				2,700
Supplies				1,000
Site Upkeep				1,000
Miscellaneous				1,000
TOTAL OPERATING COSTS - ANNUAL				45,700
TOTAL BUY-BACK FOR ALUMINUM (300 lbs/day at $.15/lb)				16,400
TOTAL ANNUALIZED COSTS				81,454

For Vail and Montrose, dropoff centers for paper and aluminum were developed; for Loveland, a combination dropoff/aluminum buy-back center was developed. Because there can be no one "typical" operation in Denver, costs in Denver would be highly variable; therefore, a Denver system was not developed or costed. It should be emphasized that the type and costs of an actual system for each one of these communities would be very case-specific and are likely to differ substantially from these cost estimates. For example, if used equipment were available, or if donations of material, equipment, labor, etc. could be obtained, the cost estimates would change dramatically. However, as a general indicator, the systems in Tables 16 and 17 will suffice. Using the recycling scenarios presented above, cost/revenue comparisons can be made as follows:

	Loveland	Montrose	Vail
Annual System Cost	$ 81,454	$ 27,916	$ 27,916
Annual Revenue	$ 128,000	$ 28,100	$ 26,600
Annual Profit or Loss	$ 46,546	$ 184	$ -1,316

If the amount of money which would have been spent on landfill disposal were credited (as a revenue) to the source separation systems, the cost/revenue comparison would be:

	Loveland	Montrose	Vail
Estimated Landfill Costs ($/ton)	$ 3.60	$ 4.30	$ 3.15
Tons Recycled per day	3.7	.3	.2
Additional Annual Revenue	$ 4,862	$ 471	$ 230
Total Annual Profit or Loss (including profit or loss from above)	$51,408	$ 655	$-1,086

Experience in California (as expressed in "Energy Analysis of Secondary Material Use in Product Manufacture," California Solid Waste Management Board) may shed further light on the situation. Generally, the appropriate collection method relates to volume handled and is estimated to be:

- drop-off center: 10-50 tons per month;
- buy-back: 50-500 tons per month;
- curbside collection: 100 - 600 tons per month.

Each system will be unique in terms of staffing, material processing, storage, transportation equipment and degree of subsidy (e.g. volunteer help, donated equipment, and grants from various groups and levels of government). Levels of sophistication and costs increase from drop-off through curbside collection.

The drop-off type system is characterized by a monthly throughput of less than 50 tons per month of recyclables (paper, aluminum, ferrous cans, and glass), nearly all volunteer help, and donated land and equipment.

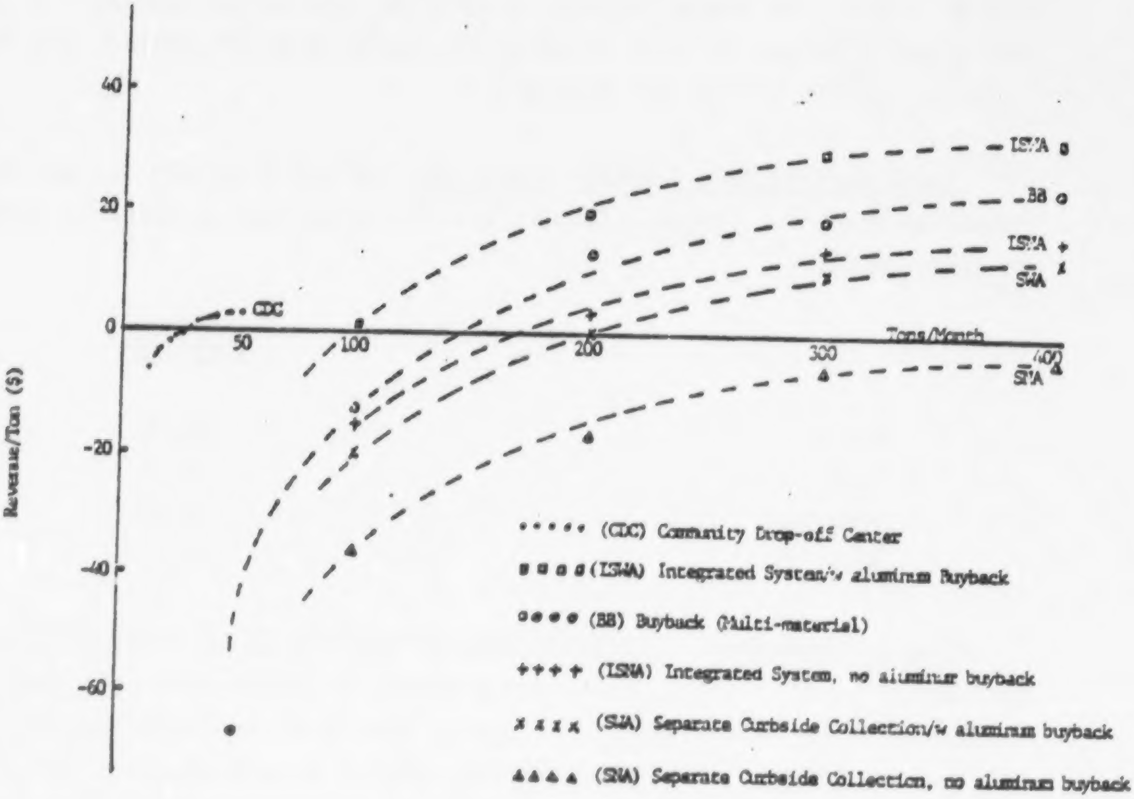
Curbside collection systems have generally evolved from existing drop-off recycling centers in order to increase tonnages of recycled materials from residences. One collection method used for source separated materials employs several auxiliary small capacity 3-wheeled scooters whose manueverability facilitates pick-up in high density residential areas. These vehicles work in conjunction with a large capacity transfer truck. Another system involves the use of a flatbed truck with or without numerous one to two cubic yard bins for the collection of newsprint, mixed glass, aluminum, and ferrous metals.

Attempts to have employees of the residential waste collection service pick-up recyclable materials in addition to regular garbage has had little success. Employees resent the extra time required and concomittantly, effective integrated collection vehicles are not yet available.

To provide a perspective of the relative net revenues (net revenue = costs - revenues received for sale of the recyclables) associated with each of these systems, Figure 9 presents a financial comparison of the various source separation systems from actual operations in California. Figure 9 demonstrates that

FIGURE 9

FINANCIAL COMPARISON OF RECYCLING SYSTEMS IN CALIFORNIA



Source: State of California, Energy Analysis of Secondary Material Use in Product Manufacture, 1980 an aluminum buy-back program in any system contributes significantly to its economic viability.

Using the California experience as a basis, only Denver among the representative communities could support a curbside collection system. A buy-back system would be appropriate in Loveland, while drop-off centers are the most practical option in Vail and Montrose.

Space Savings from Landfill Diversion. According to the maximum practical recycling scenarios discussed above, the following land at landfill sites could be saved yearly:

	Acres/Year
Denver	25.15
Loveland	0.24
Montrose	0.019
Vail	0.013

Energy Production. A waste-to-energy facility could process a significant portion of Denver's waste stream for purposes of energy recovery. The City and County of Denver is seriously considering this solid waste management option at the current time. Table 18 presents a simplified cost analysis for a 450 ton per day (TPD) incineration facility with heat recovery in Denver. A tipping fee of $7 per ton would be necessary to ensure a facility breakeven point. Current tipping fees at Denver's landfills are on the order of $5 per ton and are expected to rise to $7 per ton in the near future. If comprehensive methane gas and leachate control and monitoring actions were added to the "real cost" of operating a landfill, the total required tipping fee at a 450 TPD landfill in Denver could rise from $7 to $10 per ton (based upon a 1980 Fred C. Hart Associates study entitled "Technology, Prevalence and Economics of Landfill Disposal of Solid Waste" completed for the U.S. EPA). Therefore, the resource recovery option appears to be very viable under these conditions.

TABLE 18

COST ANALYSIS FOR A 450 TON PER DAY DENVER WASTE-TO-ENERGY FACILITY

	$/ton
1. Debt Service (include capital cost, fees, interest, etc.)	16
2. Operating and Maintenance Cost	16
3. Transportation Cost (assumed to be $0 for comparison purposes)	0
4. Energy Product Revenue	25

Required tipping fee = 16 + 16 - 25 = $7/ton

Source: City and County of Denver, 1982

Additionally, since transportation costs generally account for a majority of the total cost of waste collection and disposal (currently estimated to be an average of $40/ton), the transportation cost savings obtained through efficient siting of a waste-to-energy facility may further favor the resource recovery option.

Assuming that an energy user could be found in the other representative communities, comparisons can also be made between the resource recovery facility and landfill tipping fees (see Table 3). For comparative purposes, a model 25 TPD waste-to-energy facility was developed and costed based on a review of the literature (see Table 19). Comparison of the tipping fees are as follows:

	Loveland	Montrose	Vail
Estimated Landfill Cost ($/ton)	$ 3.60	$ 4.30	$ 3.15
Energy Recovery Facility ($/ton)	22.00	22.00	22.00

Therefore, even if landfill costs are grossly underestimated, the energy recovery option does not appear to be economically viable in the short-term.

Waste-to-energy incineration could have direct implications in other cities in Colorado. Feasibility studies have recently been conducted in both Eagle County (includes Vail), Larimer County (includes Loveland) and Boulder County. There are no secure markets for the recovered energy resources in any of these three areas. However, Boulder and the Public Service Company are continuing negotiations regarding the sale of steam and/or electricity from a modular incinerator.

Several references, which provide institutional and technical guidance, exist in the literature regarding waste-to-energy incinerators. A reference

TABLE 19

COST ANALYSIS FOR A 25 TON PER DAY INCINERATION FACILITY

1. Capital Costs

Capital Costs = \$1,500,000
Amortized capital cost per ton processed

$$= \frac{\text{Capital costs (\$)} \times \text{CRF}[1]}{\text{365 days/yr.} \times \text{design capacity (TPD)} \times \text{utilization factor}[2]}$$

$$= \frac{\$1{,}500{,}000 \times 0.11746}{365 \times 25 \times .85}$$

$$= \$22.71$$

Say \$23.00/ton

2. Operating and Maintenance Costs

= \$21.00 per ton processed

3. Transportation Costs - assumed to be \$0

4. Revenues Generated

$$\text{Revenues per ton processed} = 4{,}500\ \frac{\text{Btu}}{\text{lb.}} \times 2{,}000\ \frac{\text{lbs}}{\text{ton}} \times 0.55\ \text{(efficiency)}$$

$$\times \frac{\$4.50}{10^6\,\text{Btu}} = \$22.28/\text{ton}$$

Say \$22.00/ton

5. Tipping Fee

Tipping Fee = Capital Costs + O&M Costs + Transportation Costs - Revenues
= \$23 + \$21 + \$0 - \$22 = \$22

6. Energy Generated Per Day[3]

$$= 25\ \text{TPD} \times 4{,}500\ \frac{\text{Btu}}{\text{lb.}} \times 2{,}000\ \frac{\text{lbs.}}{\text{ton}} \times 0.55\ \text{(efficiency)}$$

$$\times 0.85\ \text{(utilization factor)}$$

$$= 105 \times 10^6\ \text{Btu/day}$$

$$\div 5.8 \times 10^6\ \text{Btu/barrels of oil}$$

equivalent to 18 barrels of oil in energy value.

1. CRF = Capital Recovery Factor (20 years at 10% interest)

2. A utilization factor accounts for downtime of the incinerator due to maintenance and mechanical failures.

3. The energy generated from a solid waste incinerator is in the form of steam or electricity. The conversion to barrels of oil is presented to provide a frame of reference.

entitled "Small Modular Incinerator Systems with Heat Recovery: A Technical, Environmental and Economic Evaluation"[1] provides good background material for incinerator systems the size and type of which might be utilized in Colorado in the near future.

Summary of Resource Recovery Analysis for Representative Communities. A number of concepts and evaluative techniques have been introduced in order to provide information to be used in evaluating the costs and benefits of source separation and waste-to-energy options. These concepts and techniques have been applied to the four Colorado representative communities in order to estimate:

- current landfill costs;
- maximum practical tons (MPT) recycled;
- energy savings from recycling the MPT;
- potential revenues from recycling the MPT;
- annual profit or loss from one potential recycling operation in each community;
- revenue saved by diverting the MPT from the landfill through recycling;
- space saved by diverting the MPT from the landfill through recycling; and
- tipping fee for one potential waste-to-energy operation in each community.

Table 20 summarizes the results of analysis for each representative community.

---

[1] Frounfelker, Richard, 1979, Washington, D.C., U.S. Environmental Protection Agency, 65 p.

TABLE 20
SUMMARY OF RESOURCE RECOVERY ANALYSES

	Denver	Loveland	Montrose	Vail
Current Estimated Landfill Cost ($/ton)	$ 5.00	$ 3.60	$ 4.30	$ 3.15
Maximum Practical Tons Recycled (tons/day)	392	3.7	.3	.2
Energy Savings from Recycling (million Btu/day)	6,935	79	18	17.1
Potential Revenues from Recycling ($/year)	$11,500,000	$128,000	$28,100	$26,600
Annual Profit or Loss from One Potential Recycling operation ($/year)	highly variable	$ 46,546	$ 184	-$ 1,316
Revenue Saved by Diverting Wastes from Landfill through Recycling ($/year)	$ 715,400	$ 4,862	$ 471	$ 230
Space Saved by Diverting Wastes from Landfill through Recycling (acres/year)	25.15	0.24	0.019	0.013
Tipping Fee for one Potential Waste-to-Energy Facility ($/ton)	$ 7.00	$ 22.00	$ 22.00	$ 22.00

V. POLICY IMPLICATIONS OF THE ANALYSIS

Potential State Government Roles

There are several areas where an increased role by Colorado State Government may be appropriate. This supportive role could concentrate on the elimination of barriers and constraints so that resource recovery options can be adequately considered in the decision-making process at the local level. This process has already been initiated by the State government. Of special note in this regard are the landfill tax and/or user surcharge established in the 1981 hazardous waste legislation (S.B. 519). These funds can be appropriated by the County governments for the purpose of financing solid waste management activities including resource recovery. The State has also shown its far-sightedness in other areas such as alternative energy supply and conservation tax credits. This program is among the best in the nation. There is a possibility for similar programs for resource recovery. These programs allow implementation at the local government or individual level, yet provide the necessary stimulus at the State level to encourage actions which have a long term public benefit.

Two general areas in which state government could play an active role involve information and markets. Both of these areas can act as major obstacles to resource recovery consideration and implementation, yet can be overcome in certain instances through appropriate strategies and awareness. The information role would fill important data gaps necessary for proper decision-making, while the market role would provide direct and/or indirect stimulus of the demand for secondary materials or energy from wastes. State action could lead to:

- increased recognition of solid waste management problems which exist now or will exist in the future;
- increased consideration of resource recovery in local government and private sector decision-making processes; and
- stimulation of private sector activities through incentives and enhanced markets.

Discussion of each category of possible state action follows below.

Information. Informational constraints are a major hindrance in the consideration of the resource recovery option by local governments. Vital information currently not readily available includes:

- accurate landfill and other solid waste management cost data;
- waste characterization (quantity and quality) data;
- the availability of technical assistance for local decision-makers; and
- general educational materials on the benefits and costs of the various management options for the general public and local government decision-makers.

A comprehensive effort to obtain and disseminate this information would be of great value to planners assessing the case-specific feasibility of resource recovery. Such actions would also provide an impetus to re-evaluate existing solid waste practices which may no longer be appropriate due to excessive costs, environmental problems, etc.

Markets. In any discussion of the consideration and/or implementation of resource recovery, the factor of markets must included. The markets which control the economic viability of resource recovery generally are not influenced by a single community. The existence of markets (or the development of markets where none exist) is of critical importance in the successful achievement of resource recovery implementation. Certain materials (e.g., aluminum cans) have established stable markets which are attractive to a wide variety of individuals groups and businesses. Other materials have either less stable or highly localized markets which are not readily accessible to those who generate or collect wastes.

In resource recovery projects, there are inherent risks which act as deterrents to investment. The incentives that can be used to compensate for the risks must be consonant with the particular markets, technology and economic uncertainties. Unproven technologies may require research and development while technologies that are already successful may require incentives to encourage commercialization. Low technology options may simply require initial front-end capital. Following is a brief description and analysis of the types of economic incentives which should be considered as possibilities for government involvement in resource recovery. Table 21 provides a summary of the effects these incentives tend to have on decision making.

Incentives such as floor prices and contract prices are grouped under the broad term of price incentives. Price incentives aim to encourage activity by assuring profits to suppliers through control of the end product price. These are also called price supports or guarantees. More specifically, floor pricing refers to a scenario whereby the government agrees to buy all of the product and then resells the product at market prices. The advantages to this type of incentive program are that the government does not choose processes for development, efficiency is encouraged, very little administrative effort is required and the initial risk of the project falls largely on the investor. Disadvantages include a possibly overwhelming financial burden to the government. The potential burden could be reduced by requirements for prior government approval of development plans. Also, artificial pricing of any kind may contribute to artificially higher consumption of a more expensive product which results in higher cost to society as a whole.

Contract pricing is essentially the same as floor pricing except that contracts are individually negotiated with sponsors of specific projects. Under this system, the government chooses technological processes for development by awarding preferential contract terms. It also allows the government to limit its financial liability by controlling output. Again, this may lead to an artificially low price for the product and consequent overuse. Other disadvantages are that administrative costs are much higher as compared to floor pricing and efficiencies may be sacrificed due to loss of typical market pressures.

Tax incentives are another broad grouping of economic incentives. Tax incentives operate more indirectly than price incentives but have the same objective of reducing risk and increasing profitability. For example, with accelerated depreciation, (one type of tax incentive), capital and financing costs of the project are partially offset. The government "pays" for tax incentives in foregone income.

TABLE 21

EFFECT OF VARIOUS INCENTIVES ON DECISION-MAKING

Type of Incentive	**Effects on Decision-Making**		
	Government	**Private**	**Non-Profit**
Price Incentives	Potential major negative budgetary implications under marginal market conditions--relies on private sector to solve problems	Strong incentive for expansion of existing framework through risk reduction	Strong incentive; integration into private sector market framework
Tax Incentives	Foregone income to government (negative budget implications)	Strong incentives for expansion of existing framework through risk reduction	No immediate incentive became of tax free status--indirect impact because of increased private sector marketing activity
Loan Guarantees	Substantial risk of negative budget implications in poor market conditions	Major risk reduction technique encouraging entrance into marginal markets	Major new source of potential revenue for groups with little financing credibility
Grants	Potential negative budget impacts, but gives substantial discretion to government to decide what is appropriate	Not a major incentive because of short-term impact and minor market stimulus	Very important to small capital-short groups needing limited funding
Direct, low-interest loans	Some foregone capital due to lower interest rates	Important for new market areas or new smaller operations	Very important to small capital-short groups needing limited funding
Surcharge (e.g.,at the landfill)	Additional revenues which can be diverted to specified activities such as resource recovery	Additional costs of landfilling improves consideration of resource recovery as an option if markets exist	No immediate incentive; indirect impact because of increased opportunities if private responds appropriately
Landfill Diversion Credit	Potential major negative budget impacts--if the objective of diverting waste from landfill is high priority, will be very effective	Significant new incentive to divert wastes from landfill and recover substantial resources in many cases	Significant new incentive to divert wastes from landfill and recover substantial resources in many cases

Risk reduction incentives operate by reducing the risk taken by the investor. The risk is shifted, in part or wholly, to the government. Two common types of risk reducing incentives are loan guarantees and insurance. A loan guarantee is a government committment to guarantee a percentage of loans for the capital costs of a project. This arrangement results in lower interest rates to the project sponsor as the investor's risks are reduced. The low-interest debt can result in a lower selling price of the product. Obviously, the major disadvantage is the possibility of a default and a resulting financial burden to the government. Some of the risk to the government can be reduced by inversely adjusting the loan guarantee percentage to the risk of failure. However, this might be counter productive to the original intent of the incentive plan as more risky projects win lower loan guarantees. Loan guarantees can also encourage early shutdown of projects as anytime a project cannot earn its fixed costs and operating costs, the tendency could be to default. The failure of a project will result in costs to the general taxpayer as opposed to the private sector.

Insurance is another form of incentive that can reduce risk. Under this incentive program the government requires that all resource recovery projects purchase default insurance. Premiums are set according to the degree of risk of the project. The government maintains a fund to cover defaults and may provide bonds to increase collateral. Insurance incentives have similar advantages and disadvantages to loan guarantees except risks are shared by the government and the developers.

Capital access incentives decrease the capital needed to participate in a project. These take the form of grants or direct government loans.

Grants may be especially important to cover capital costs of small operations with limited resources. Other states have successfully used grants to stimulate resource recovery consideration and implementation. California has a well-developed resource recovery program in which grants play a very significant role. Montana has encouraged resource recovery and other renewable energy and conservation options through grant program funds that were collected through coal severance taxes. Recently, a state grant was provided for a waste-to-energy facility in Livingston, Montana. Competitive bidding for grant money encourages efficiency as does cost-plus or percentage-of-total-cost arrangements.

This method is advantageous because it does not affect financial markets (unless the government must borrow) because money is coming from public funds. However, this is also a costly alternative because the government is responsible for costs whether the project is successful or not.

Direct loans are a form of capital access incentive. A governmental entity will allocate a certain amount of its budget specifically for low-interest loans for specific projects. Typically, payments start after the project has become operable. Advantages and disadvantages are the same as for grants except that if the project is successful the government will not be burdened with capital costs.

Another way to encourage investment and commercialization is through the use of surcharges. Surcharges are levied much like a tax, to help pay for selected incentive programs. The surcharge may be levied against specific users (e.g. at the landfill) or on products so that the largest users contribute the greatest amounts. The funds collected can be allocated to specific uses (such as resource recovery projects). In this way, the government takes no direct risk in project implementation because funds were allocated to reach specific goals.

Another interesting idea with similar goals to that of a surcharge is a landfill diversion credit. This provides an immediate stimulus to prevent wastes from going to the landfill. The credit serves to extend the geographic limits of product markets, so that materials which might otherwise not be saleable in a local market may, under new circumstances, find a regional or national market. This incentive, then, should directly lead to both a reduction in landfill use and encourage resource recovery. This situation, of course, still depends upon markets which, even on the national level, are unstable in many cases. In other words, the landfill diversion credit may not allow the demand for Colorado recovered materials to change to the extent necessary to make significant market impacts.

Other incentive programs could be modeled after creative programs which have been designed to attack a specific solid waste problem. For example, North Dakota and Montana have implemented abandoned car recovery programs which have met with great success in removing and reclaiming abandoned cars as well as providing a monetary gain to county economies.

All of these incentives should stimulate the viability of various resource recovery options. However, it is ultimately the demand for the recovered resources which determines viability. There are markets in some cases for energy products such as steam and/or electricity. Markets for materials are highly variable and difficult to predict. The private sector must necessarily play the dominant role in determining how much each material market can absorb. Where appropriate, government could intervene to influence the demand for recycled goods and services. A major question associated with this option is whether it can be effective at the State, as opposed to the national, level. Government actions directly affecting demand could include:

- state procurement of a required percentage of recycled goods;
- legislation requiring a percentage of recycled goods in the manufacture of certain new products; or
- elimination of unjustifiable materials quality standards that exclude recycled goods.

These actions would not have a substantial impact on overall demand because of the low percentages of goods purchased by State Government and the relatively small amount of goods produced in Colorado. The State of Colorado currently has a recycled product procurement policy which has met with limited success. Under this program, bids for recycled goods are solicited from vendors. State purchasing agents then determine the amount or percentage of recycled materials in the products, the weight of the goods, and the multiplier to be used based on the energy savings of recycling that particular material. With this information, the bid is adjusted so that the recycled goods compete more favorably. The approximate formula is presented below:

Bid Price - [Weight of the Article x Percentage
of Recycled Material x Multiplier (Cost of a Btu)]
= Adjusted Price

The adjusted price is then used as the bid price when making purchasing decisions. However, state procurement officials report that most dealers in Colorado do not supply bids of recycled goods or will not admit that recycled materials are included.

Potential County and Municipal Government Roles

Colorado counties and municipalities currently have some valuable tools to encourage resource recovery. One is in the form of the landfill user's surcharge which was established by Senate Bill 519, Section 5, 30-20-115. This action permits counties to collect service charges from users of solid waste disposal sites and facilities for the purpose of financing solid waste management (including resource recovery) in the county. The use of the funds is not limited to on-site operations but is left up to the discretion of the particular county. To date, only Boulder County has made use of its authority to impose such a surcharge. The county began assigning a fee of approximately $0.20 per cubic yard of compacted garbage ($0.15/carload, $0.50/pickup truck load) in October, 1981. From October through December, 1981, approximately $27,000 was collected and placed in an escrow account. These funds are allocated by the Board of County Commissioners on the advice of the Solid Waste Advisory Committee. Following a Request for Proposals in the fall of 1981, approximately $75,000 has been allocated to Eco-Cycle for equipment and personnel. Another $35,000 was allocated to Boulder County as repayment on a loan formerly made to Eco-Cycle. A smaller amount was earmarked for the purchase of a semi-trailer to replace a greenbox collection site. Citizens in Summit and Larimer Counties have also requested the imposition of a landfill surcharge for resource recovery, though no definite decision has as yet been made in either case.

The Colorado Legislature, through another action, Senate Bill 481, also cleared the way for cities or towns to establish 'heating and cooling' utilities (Section 5, 31-32-105). The Act specifically authorizes municipalities to operate utilities with energy derived from biomass and other renewable resources. "Biomass" can be broadly interpreted as including municipal waste-to-energy systems.

Municipal grants have been an important element in the success of some of the recycling organizations in Colorado. For example, the City of Boulder and Boulder County have contributed approximately $175,000 in grants to Eco-Cycle since its inception in 1976. The Ft. Collins recycling organization, Recycle Something, has received grant financial assistance from the city in the form of land and warehouse space and $64,000 per year of revenue sharing funds.

All of these county and municipal actions suggest that the first step a governmental agency must accomplish is a recognition of current and potential solid waste management problems and their associated environmental and economic costs. Only after this recognition can steps be taken to alleivate or prevent specific problems.

State Commitment to Resource Recovery

Individual State incentives could be initiated through amending existing legislation or creating new policies and/or legislation. A clear statement of State philosophy is an important first step. The State's resource recovery philosophy should allow for:

- a broad, non-restrictive approach;
- an emphasis on filling gaps in the market system rather than duplicating or hindering existing efforts;
- the removal of obstacles so that when market forces allow, implementation can occur; and,
- a focus on recognition of current and/or future solid waste management problems.

This philosophy reflects cognizance of the fact that habits, vested interests, and economic realities must change gradually. A withdrawal from dependence upon landfills must occur gradually. The philosophy also reflects the realization that although there is a natural evolution towards resource recovery, actions taken in the near term can provide a supportive role in encouraging this evolution. Awareness and education can only be positive factors in achieving the long term solid waste management goals.

Overall, it is clear that landfilling will remain the prevailing waste management technique in the near term. Colorado will be faced with tremendous growth opportunities and costs. The evolutionary process towards resource recovery could be an important component in planning for growth. The framework for consideration and implementation of resource recovery should be established now in order to avoid mistakes and unnecessary costs later.

VI. CONCLUSIONS AND RECOMMENDATIONS

The following conclusions and recommendations were developed by the Resource Recovery Subcommittee of the Solid Waste Advisory Committee following review of the report by members of the Subcommittee and representatives of EPA Region VIII and the Colorado Department of Health.

Conclusions

1. Solid waste management in Colorado is handled by an unintegrated and diverse group of private and public sector entities.

2. Accurate and complete data on solid waste management in Colorado is difficult to obtain because of institutional factors such as fragmented management responsibility and different accounting procedures within the public sector and the classification of data by the private sector as proprietary information.

3. Resource recovery in Colorado is hampered by the state's geographic distance from users of secondary materials, a lack of knowledge about resource recovery by public and private sector decision-makers, and the difficulty of accurately comparing costs of landfilling with that of the costs of the various resource recovery options.

4. Many existing landfills in Colorado are confronted by problems such as limited future capacity, inadequate operating procedures and potential or existing groundwater and surface water contamination. New landfills will be sited further from population centers because of competition for undeveloped land and because of growing public opposition to siting landfills near populated areas.

5. The greatest existing and potential governmental support for resource recovery in Colorado is at the municipal and county levels. A comprehensive Colorado resource recovery program is in an early phase of development. Federal support for municipal solid waste studies or projects is being completely withdrawn.

6. The economic and political feasibility of comprehensive material and energy recovery will continue to improve, while disposal by landfilling will continue to grow more difficult and expensive in all of Colorado, especially along the Front Range. This conclusion is predicated on energy costs continuing to increase, land costs continuing to escalate, and landfills being located at greater distances from the points of refuse generation (resulting in increased transportation costs).

Recommendations

1. Information on waste management and resource recovery should be developed for public and private sector decision-makers and the general public. To facilitate the flow of information, a central clearinghouse of waste management information should be established in the state. The Department of Health should staff the clearinghouse.

2. The governor or legislature should empanel a temporary legislative committee charged with conducting a review and evaluation of resource recovery in Colorado. Following the review, recommendations should be made on further State involvement. Adequate funding for staff in preparing the committee's report should be provided.

3. Governments should increase their use of products made from recycled materials, recycle their own wastes and encourage business and industry to do the same. Additionally, government and industry should consider waste-to-energy as a waste management option.

4. Source separation for material recovery and waste-to-energy systems should be considered in tandem, not as mutually exclusive activities. Present and future opportunities for material recovery must be considered when planning refuse-to-energy facilities. Any waste flow control legislation should be written so as to not preclude source separation activities.

5. If public funds, in the form of grants or loans, are made available for resource recovery efforts, all types of organizations, both public and private, should be allowed to compete for those funds on an equal basis.

6. If a comprehensive State resource recovery program is determined to be appropriate, it is imperative that resource recovery become a bipartisan issue. A liaison should be created between the governor and the state legislature to affect the above recommendations.

APPENDIX I

NOTE: The following material from the State of South Dakota is intended to provide a simple methodology for estimating costs of solid waste disposal at a particular site. Numbers included in the sample tables are presented to clarify the cost analysis. Numbers utilized are not intended to provide a baseline for comparison. Current costs for equipment, land, labor and construction may be 50% - 100% or greater than the example numbers.

Costs and Returns

of Solid Waste Disposal in Sanitary Landfills

By F. F. Kerr, Extension water resources specialist
G. R. Durland, Extension agricultural engineer

Reproduced from best available copy.

Most units of government feel that the disposal of solid wastes should be wholly or at least partially a self financing public service. The alternative is for local government to absorb all costs, with revenues collected through taxation.

Assuming that government wants to make the service self financing, what charge per ton of waste handled must be made to cover depreciation on needed equipment, pay operating costs and retire the cost of land used?

Land costs may be in the form of yearly lease charges, land purchased for landfill use that will be sold when the site is full, or land purchased that will be retained for uses such as public parks, maintenance facilities for government equipment, or for some other public use.

This publication contains a method for computing what service charges must be made to retire all disposal capital and operating costs. Collection costs are not included in this publication.

A format is provided, showing an example. But since no two situations will be the same, blank spaces have been provided for units of government to insert figures that apply to their situations. The objective is to come up with a charge per ton of waste handled that will retire all costs during the life of the site. Knowing this, units of government can then decide if they wish to use this charge per ton and make the service entirely self financing or if they wish to lower the charge per ton and pay part of the costs out of tax revenues.

The example used is the same as the one used in FS 613 where acreage requirements were computed. Table 1 summarizes the example situation and provides space for your situation.

The example assumes that the land will be purchased by the unit of government and retained for future public use.

Table 1

	Example Situation	Your Situation
Population to be served	30,000	______
Estimated yield per person per day	4.25 Lbs	______Lbs
Yearly yield	23,269 T	______T
Acreage needed	30 A	______A
Design life of the site	10 Yrs	______Yrs

Equipment Costs

Assume for purposes of the example, purchase of a $50,000 compactor to be used at the landfill site 100 percent of the time. A $27,000, 1¾ yard wheel-type loader already owned is allocated to the landfill 20 percent of the time. An 11 yard, $48,000, self loading elevating grader, already owned, is allocated to the landfill 10 percent of its time for stockpiling cover material. Table 2 summarizes equipment needs and annual depreciation charges.

Land and Associated Costs

The example further assumes that land costs $250 per acre for the 30 acres needed, or $7,500. Fencing would amount to $440. Gates, locks and incidentals are assumed at $300, and an operators' shelter with sanitary facilities at $2,400.

Site preparation costs vary from almost zero to a significant figure. If the site is an unobstructed natural depression near an all weather road, costs will be very low. If a tree filled gully a long distance from an all weather road is to be used, costs will be significant. The example arbitrarily assumes $1,000 for this cost.

Table 2
Yearly Equipment Depreciation

	Example Equipment	Your Equipment
Compactor	$50,000.00	$
Wheel-type loader $27,000x$20%	5,400.00	$
Elevating grader $48,000x10%	4,800.00	$
		$
		$
Total equipment value	$60,200	$
Assuming a 10 year life for the example with a 20% reclaim value, yearly depreciation = 60,200x80% = / 10 years	$ 4,816.00	
Assuming a ____ year life for your equipment with a ____% reclaim value, yearly depreciation = $____ x ____% = / ____years		$

Table 3
Yearly Land and Associated Costs

	Example Costs	Your Costs
Land	$ 7,500.00	$
Site preparation	1,000.00	$
Fencing	440.00	$
Incidentals	300.00	$
Shelter	2,400.00	$
Example Total	$11,640.00	
Your Total		$

yearly land charge = total land charge / design life = $11,640 / 10 years = $1,164.00

your yearly land charge = your total land charge / your design life = $____ / ____years = $____

Annual Operating Costs

Principle operating costs are labor, fuel and repairs for equipment. Some billing and bookkeeping cost will be involved, but since they become a part of other bookkeeping needs of the governing unit they are not significant in themselves. A record should be kept for future reference of tonnage or volume handled.

Table 4 gives operating costs as assumed for the example with space for computing your costs.

The cost of a scale is omitted, since many governing boards feel that tonnages can be estimated reasonably well. Some consider adding a scale after some of the immediate costs have been retired.

The basic costs shown in tables 2, 3 and 4 can be inserted in computation table No. 5.

Table 4
Operating Costs

	Example Costs	Your Costs
Personnel—2 men including insurance, social security etc.)	$15,000.00	$
Fuel and lubrication	2,300.00	$
Repairs	5,250.00	$
Insurance	650.00	$
Annual operating costs for example	$23,200.00	
Annual operating costs for your operation		$

Table 5
Computation Table

Cost Factors	Example Summary	Your Summary
1. Yearly equipment depreciation (Table 2)	$ 4,816.00	$
2. Yearly land and associated cost		
Using Assumption No. 1 (table 3)[1]	1,164.00	$
Using Assumption No. 2[2]		$
Using Assumption No. 3[3]		$
3. Yearly interest on investment and/or reserve fund[4]		$
4. Annual operating cost (table 4)	$23,200.00	$
Example total annual costs	$29,180.00	
Your total annual costs		$
Income Factors		
Anticipated annual waste yield from the example (table 1)	23,269 T	
Anticipated annual waste from your facility (table 1)		$

Cost Factors	Example Summary	Your Summary
Charges Needed		

Per Ton charges needed to retire

$$\text{all costs} = \frac{\text{total annual costs}}{\text{total annual T}} = \frac{\$29{,}180}{23{,}269\ \text{T}} = \$1.254$$

Your per T. charges needed to retire all costs

$$\frac{\text{your total annual costs}}{\text{your total annual T}} = \frac{\$\_\_\_\_\_\_}{\_\_\_\text{Tons}} = \$\_\_\_\_\_\_$$

[1] Assumption is that land will be purchased and retained for public use. Usually it is desirable to charge off the land cost to waste disposal, since future use will likely not be revenue producing.

[2] Assumption is that land will be sold after site is complete. Therefore it should be safe to assume a land charge of zero, but an annual charge covering fencing, incidentals and structures should be included.

[3] Assumption is that the land is leased, and the land charge equals the yearly rent paid plus an annual charge for fencing, incidentals and structures.

[4] If the governing body must incur an indebtedness to meet all or a part of the costs involved, obviously the service charge should retire the interest paid on the amount of the debt. Even though an indebtedness is not incurred, some units of government use this technique to built a reserve fund so that money is available for new equipment and land when it must be purchased at a future date (10 years in the case of the example). This technique is common practice in business but is relatively new in government. It is called Capital Improvements Budgeting.

To Buy or Not To Buy Land

The decision to purchase land to keep for public use, to purchase land to sell after the site is full, or to lease land will be influenced by many things such as need for more public use land, availability of land, land costs and perhaps others.

To give some idea of the dollar difference between the alternatives, the example used here has been refigured and is shown in table 6.

Table 6
Buying or Not Buying Land

	Per Ton Charge to break even
Assumption No. 1 (as used in the example) where land is to be retained for public use	$1.254
Assumption No. 2—where land is to be sold after site is completed	$1.222
Assumption No. 3—where land is leased—(a figure of $20.00 per acre per year is used here)	$1.248

Since dollar differences are so small, units of government should be more concerned with their need for public use land than with choosing the least costly alternative.

Determining a Rate Schedule

Computations so far are all in terms of tons. If a scale is purchased the rate schedule is no problem since everything is weighed. If there is no scale, tons must be converted to compacted cubic yards.

Compactor trucks are rated according to the cubic yards they can compact, so this is a simple conversion. The rule of thumb used in conversion is that one cubic yard of compacted wastes will weigh from 800 to 1000 pounds with the 800 pound figure occurring more frequently.

Going back to the example used where the per ton rate was determined to be $1.25, and using 850 pounds per cubic yard for conversion, the break-even rate would be ($1.25 x 850/2000) or $.53 per cubic

Reproduced from best available copy.

yard. This would establish a rate of $6.36 per load for a 12 cubic yard compactor.

In the case of non-compacted loads delivered to the site the rate schedule becomes something of an educated guess.

Most units of government establish a rate schedule for non-compacted wastes based on the size of the conveyance used for delivery. One sanitary landfill's rate schedule for such conveyances is shown below.

1. Small trailers with a rack (about 2 yards)—$.75 per load
2. Large trailers with rack or small pickup w/o rack (about 3 yds)—$1.00 per load
3. Large pickup with rack (about 5 yds)—1.25 per load
4. Small trucks (5 to 9 yds)—$2.00 per load
5. Large trucks (10 to 12 yds)—$2.75 per load

Obviously this rate schedule is a rather arbitrary one established in the hope that, for example, pickup loads of old tires that are heavy and difficult to compact will average out with loads of paper cartons that are light and compact easily.

APPENDIX II

FURTHER SOURCES OF RESOURCE RECOVERY INFORMATION

Organizations

Paul Parker
National Association of Recycling Industries
330 Madison Avenue
New York, N.Y. 10017

Jim Fowler
Institute of Scrap Iron and Steel
1627 K. Street NW
Washington, D.C. 20006

Olie Webb
Colorado Association of Commerce and Industry
1390 Logan Street, Suite 308
Denver, Colorado 80203
(303) 831-7411

Pete Grogan
Colorado Recycling Cooperative Association
P.O. Box 4193
Boulder, Colorado 80306
(303) 444-6634

Danamarie Schmitt
Governmental Refuse Collection and Disposal Association
P.O. Box 2941
Denver, Colorado 80201
(303) 659-2120 Ext. 217

Tony Massaro
Coloradoans for Recycling
1711 Pennsylvania Street, Suite 207
Denver, Colorado 80203
(303) 830-0294

Elaine Weaver
Colorado Counties, Inc.
1500 Grant Street, Suite 301
Denver, Colorado 80203
(303) 861-4076

Ron LeBlanc
Colorado Council of Local Energy Officials
8101 Ralston Road
Arvada, Colorado 80002
(303) 431-3000

Clara Lou Humphrey
League of Women Voters
1600 Race Street
Denver, Colorado
(303) 320-8493

National Solid Waste Management Association
1120 Connecticut Avenue NW
Washington, D.C. 20036

Government Sources

Greg Starkebaum
Colorado Department of Health
Waste Management Division
4210 E. 11th Avenue
Denver, Colorado 80220
(303) 320-8333

Ed Demos, Vicki Mattox
Denver Energy Utilization Study
City and County of Denver
Environmental Services Division
Department of Public Works
(303) 575-5767

Amy Lingg
Denver Clean Community System
Room 379
City and County Building
Denver, Colorado 80202
(303) 575-2563

Morris Johnson, William Rothenmeyer, Martha Walters
U.S. Environmental Protection Agency
1860 Lincoln Street
Denver, Colorado 80295
(303) 837-3853

Office of Energy Conservation
State of Colorado
1525 Sherman
Denver, Colorado 80203
(303) 866-4481

Al Foster
Denver Regional Council of Governments
2480 W. 26th Avenue, Suite 200B
Denver, Colorado 80211
(303) 455-1000

Active Resource Recovery Projects

Pete Grogan/Roy Young
Eco-Cycle
P.O. Box 4193
Boulder, Colorado 80306
(303) 444-6634

Tim McClure
Summit Recycling Project
Box 73
Frisco, Colorado 80443
(303) 453-1372

Recycle Something
P.O. Box 148
Ft. Collins, Colorado 80521
(303) 484-2249

Jim McNelly
Natursoil Company
5243 E. 100th Avenue
Denver, Colorado 80229
(303) 457-2897

Frank Smith
Golden Recycle Company
3000 Youngfield, Suite 230
Lakewood, Colorado 80215
(303) 277-5775

Dave Powelson
Tri-R Systems
4930 Dahlia Street
Denver, Colorado 80216
(303) 399-6351

Ken Dunwoody
Colorado Recycling
9700 W. 51st Place, Suite D-314
Arvada, Colorado 80002
(303) 431-9052

William Schaeffer
Atlas Metal and Iron Corp.
P.O. Box 5428
Denver, Colorado 80217
(303) 825-7166

APPENDIX III

ENVIRONMENTAL COMPLIANCE OF WASTE-TO-ENERGY FACILITIES IN COLORADO

A. The Permitting Process

Any resource recovery project will be confronted by a number of local, state and Federal rules, regulations and guidelines which were established to control environmental impacts of proposed actions. These potential environmental impacts will have to be identified during the initial project planning stages in order to prepare permit applications and allow time for regulatory agency review and decision. These regulatory/institutional factors can be a significant determinant of overall project feasibility and/or project scheduling due to the following:

- the permitting process is a complex, time-consuming series of actions involving a number of regulatory agencies on all governmental levels, none of which has overall regulatory control over any particular proposed project;
- the regulatory framework is constantly changing and evolving, with regulatory agencies sometimes uncertain of their specific role, and the permit applicant is often confronted by uncertainties and changes which are not readily apparent;
- pollution control requirements may affect project financing and/or economic feasibility; and
- the lack of operating experience with most types of resource recovery projects from which to gain environmental emission data and proper pollution control equipment selection.

The above listed constraints do not mean that a resource recovery facility such as the one considered for Boulder cannot be accomplished; but rather that regulatory factors and issues cannot be overlooked or given a low priority in project planning, scheduling and budgeting. Any regulatory oversight or deficiency could turn out to be the "fatal flaw" of project feasibility.

As mentioned above, there is little successful operating experience from which to gauge the overall complexities, costs, and time-frame of the resource recovery facility permitting process. There do, however, appear to be several regulatory issues/factors which deserve primary attention and can be addressed on a preliminary basis within the scope of this report. These include:

- air emissions and permit requirements;
- noise regulations; and
- solid waste generation and permit requirements.

Each is discussed in detail below.

B. Air Emissions and Permit Requirements

There are two types of air pollution regulatory controls which are of concern to potential new projects which will emit air pollutants. These include:

- limits on the concentrations or amounts of pollutants within stack emissions; and
- effects on ambient air quality.

The study area is located within the EPA-designated Denver Air Quality Control Region, which has been classified as a non-attainment area (not in compliance with ambient air quality standards) for four criteria pollutants[1]:

---

[1] A criteria pollutant is one listed in the Clean Air Act Section 108(a) which requires the preparation of a criteria document to form the scientific basis for the national ambient air quality standard.

- ozone;
- nitrous oxides;
- particulates; and
- carbon monoxide.

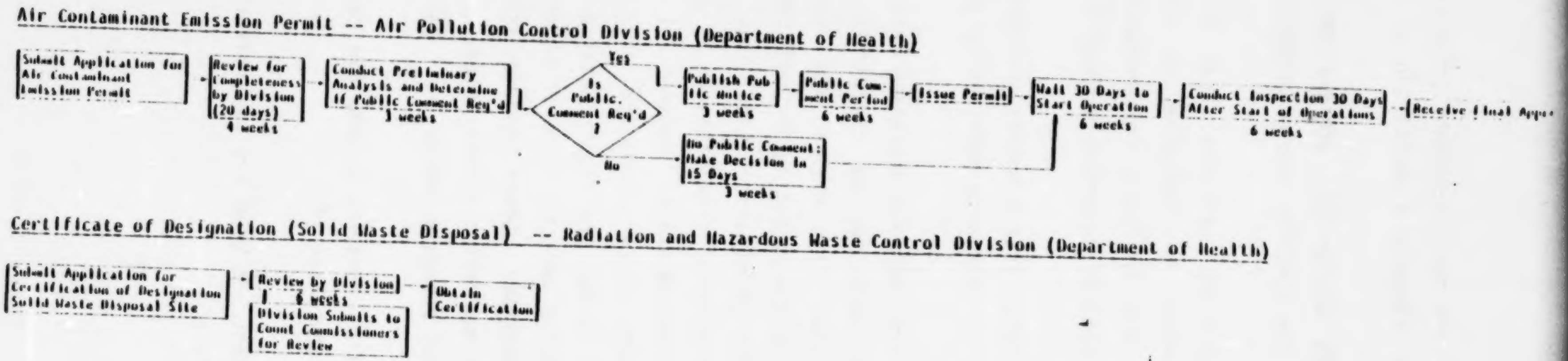
The Denver Region is in compliance with the fifth criteria pollutant, sulfur dioxide. In this situation, any new source in the region cannot further degrade ambient air quality in the non-attainment pollutant, while the additional contribution of sulfur dioxide to the ambient air quality will be limited to specified maximum incremental increases. The following discussion consists of the application of existing Colorado air pollution regulations to resource recovery options in the study area. In addition to the regulation of the five criteria pollutants discussed above, the State regulations also include emission limits for opacity, odor and hazardous air pollutants, all of which may also apply to resource recovery facilities.

1. **Modular Incinerators.** A new source modular incinerator will require a State air pollution permit and the filing of an air pollution emission notice (APEN) as described in Regulation No. 3 (see Figure 6 for a schematic representation of the air permitting process). These efforts require a thorough description and discussion of the estimated quality and composition of expected emissions (based upon actual test data or other sources acceptable in the Air Quality Control Division) as prepared by the project proponent.

According to State regulations, a modular incinerator constructed in 1981 or later would be considered a "new stationary source". In this situation, the incinerator must comply with all standards of performance including those specifically designed for incinerators (Regulation 6, Section III), which states specific requirements for the most probable major air pollution problem, that of particulates, and for associated opacity impacts.

The most critical determination will be if the incinerator would be classified as a "major stationary source." This category includes any stationary source which emits, or has the potential to emit, 100 tons per year

Figure 6: Permit Procedures for Air Emission and Solid Waste Disposal Permits


Air Contaminant Emission Permit -- Air Pollution Control Division (Department of Health)
Submit Application for Air Contaminant Emission Permit
Review for Completeness by Division (20 days)
4 weeks
Conduct Preliminary Analysis and Determine if Public Comment Req'd
3 weeks
Is Public Comment Req'd ?
Yes
No
Publish Public Notice
3 weeks
Public Comment Period
6 weeks
Issue Permit
No Public Comment: Make Decision in 15 Days
3 weeks
Wait 30 Days to Start Operation
6 weeks
Conduct Inspection 30 Days After Start of Operations
6 weeks
Receive Final App
Certificate of Designation (Solid Waste Disposal) -- Radiation and Hazardous Waste Control Division (Department of Health)
Submit Application for Certification of Designation Solid Waste Disposal Site
Review by Division
6 weeks
Division Submits to Count Commissioners for Review
Obtain Certification

Source: Fred C. Hart Associates

Reproduced from best available copy.

or more of any of the non-attainment criteria pollutants. If an incinerator were placed in this category, a permit can be granted only if:

- the proposed source will achieve the lowest achievable emission rate (LAER) for the specific source category;
- the applicant has certified that all other major stationary sources owned, operated or controlled by the applicant in Colorado are in compliance with the State Implementation Plan or are subject to and in compliance with an enforceable compliance schedule; and
- offsets (greater than a one-to-one ratio) must be obtained from existing sources for all non-attainment pollutants.

Early indications from test and operating data are that a modular incinerator of the type examined here may be classified as a major source because of particulate emissions. This may be true even though modular incinerators are touted as inherently non-polluting because the two chambers burn most, but not all, of the burnable gases and particulates. Indeed, some manufacturers claim that no special scrubbers, precipitators or other air pollution equipment are necessary on these incinerators. However, it is sometimes difficult to maintain combustion at steady state conditions for incinerators that burn municipal wastes. Municipal wastes are highly heterogeneous, and incinerators that burn such waste may require emission control equipment to meet state and/or Federal air pollution standards. Other parties attempting to obtain offsets in the Denver region have had major difficulties, a situation which makes the offset requirement the most probable regulatory fatal flaw.

There does exist, however, a possible exemption to the offset requirement under certain circumstances if:

- the applicant has used his best efforts in seeking the offsets but was unsuccessful;

- all available offsets were obtained; and
- the applicant continues to seek offsets as they become available.

With respect to direct emission limits, Table 16 shows the different types of emission substances detected in the flue gas from the North Little Rock Plant in Arkansas. Tests of the North Little Rock stack emission for their modular incinerator revealed that the emission rate for total particulates averaged 0.130 grains per standard cubic foot (gr/SCF) corrected to 12 percent CO_2 with a maximum of 0.231 gr/SCF. These average values are considerably higher than the Colorado Air Pollution Control Commission's standards for particulates (0.08 gr/SCF for 50 TPD or more). This suggests that particulate air pollution control equipment would be necessary for a Boulder operation. Control of the one attainment pollutant (sulfur dioxide), must provide for limiting incremental increases over a specified baseline to:

- 10 milligrams per cubic meter (mg/m^3) (annual arithmetic mean);
- 50 mg/m^3 (24-hour maximum); and
- 300 mg/m^3 (3-hour maximum)

Evaluation of odor, opacity and hazardous emissions cannot be properly evaluated at this time, but must not be neglected if further analysis and planning are undertaken.

2. **Refuse Derived Fuel Facilities.** The cofiring of RDF with an existing coal-fired power plant will most likely be classified as a "modification" to an existing facility. Upon modification, a facility shall become an affected facility for contaminants to which a standard applies and for which there is an increase in the emission rate to the ambient air. This is an especially important point because Public Service Company does not currently use pollution control equipment from Valmont Units 1-4. Additionally, the change in operation of an existing facility may require the filing of a revised Air Pollutant Emission Notice if a "significant" change in emissions has occurred in accordance with the Division definition of significance.

TABLE 16

NORTH LITTLE ROCK FLUE GAS EMISSION DATA

Pollutant	Emission Rate Maximum	 Average	 Minimum	lb/ton of Refuse
Particulates [1]	0.231 gr/SCF	0.130 gr/SCF	0.067 gr/SCF	3.03
SO_x	..	<10 ppm [2]	-	<0.78
NO_x	99 ppm	82 ppm	69 ppm	3.68
CO	36 ppm	29 ppm	16 ppm	1.00
HC	40 ppm	28 ppm	20 ppm	0.55
Pb [3]		4.49 mg/m^3		0.14

Source: U.S. EPA, Small Modular Incinerators with Heat Recovery.

[1] gr/SCF = grains per standard cubic foot.

[2] ppm = parts per million.

[3] mg/m^3 = milligrams per cubic meter.

Given previous RDF operating experience, an RDF facility in Boulder would normally be classed as a "major modification" according to State regulations. A major modification classification would normally result in the same three requirements (including offsets) for a major stationary source incinerator listed above in the discussion of modular incinerators. However, refuse derived fuel generated from municipal solid waste is specifically exempted from these requirements.

As with modular incinerators, there is not enough information at this time to evaluate odor, opacity and hazardous waste emissions. With respect to sulfur dioxide, the clearly stated Colorado Air Quality Control Division policy is to place the burden on new sources to prevent degradation and maintain compliance with ambient air quality standards. Therefore, with respect to a modified existing coal/RDF power plant, SO_2 emissions may not present a problem. All applicable standards must be met within 180 days of the completion of the modification. Table 17 shows a comparison of the stack emissions from burning coal only and cofiring coal with 7 percent RDF at the St. Louis, Missouri facility.

3. **Pollution Control Equipment Needs and Costs.** Since particulates were identified above as the probable major air pollution problem, this discussion will be limited to that pollutant. The control of particulates will be governed largely by established practices. Such factors as particle size, range, density, resistivity, concentration, composition, the degree of removal required, and the allowable pressure drop will all influence the selection of the appropriate control method and subsequent costs. The four most common types of particulate collectors may be arranged in order of increasing efficiency, complexity and cost:

- cyclone collectors;
- wet scrubbers;
- fabric filters; and
- electrostatic precipitators.

To date, there are no known instances in which major air pollution control equipment has been integrated into a modular incinerator facility. One supplier

TABLE 17
PARTICULATE EMISSIONS FROM THE ST. LOUIS FACILITY

Substance in Particulate	Coal Only	Coal Plus 7 Percent RDF
As	3.13	2.00
Be	0.200	0.706
Cd	0.575	1.39
Cr	12.1	16.0
Pb	11.3	54.0
Hg	0.153	0.417

Source: Sussman, David B/. Personal Communication, U.S. EPA.

(Consumat of Richmond, Virginia) is currently conducting research in this area, and has roughly estimated total air pollution equipment capital costs to be ten percent of a $500,000 modular incinerator plant. Operating cost estimates are not available.

A major resource recovery facility which burns RDF alone or cofires RDF with coal can be directly compared with the needs and costs of a major coal fired boiler. The use of RDF would not require the special use of other air pollution control equipment. Costs, however, are difficult to estimate without detailed knowledge of plant design, RDF and coal quality, and other parameters; costs are very case- and site-specific. EPA estimates for the capital costs of electrostatic precipitator particulate control range from 2.5 to 4.4 million (1976 dollars) for a 200 MW utility boiler. Assuming a 12 percent per year escalation (for five years), 1981 costs would range from 4.4 to 7.75 million. Erection and installation costs would add about 70 percent to this total, creating an installed equipment range of from $7.5 to 13.2 million for the 200 MW boiler. If a new coal-fired boiler were to be built today, capital costs would be approximately $1,000 per installed Kilowatt. Particulate control capital costs for the 200 MW boiler would, therefore, range from 2.2 to 3.9 percent of total capital cost. EPA estimates of operating costs for electrostatic precipitator particulate control range from $.56 to 1.02 million. Escalation at 12 percent per year would increase these estimates to $1 to 1.8 million in 1981 dollars.

C. Noise Regulations

Restrictions and regulations on the noise emitted from a resource recovery facility take two forms: those affecting workers, as regulated under the Occupational Safety and Health Administration (OSHA): and those affecting the general public, as regulated by the City of Boulder.

A recent study has shown that some resource recovery processes can produce noise in excess of present OSHA standards. Control of noise in such equipment by engineering design may be costly, although the option of administrative noise controls (limiting the time exposure of employees) and personal protective equipment may be sufficient in some cases.

The City of Boulder has shown its concern for the protection of the general public from excess noise through a relatively agressive noise regulation enforcement program. Current noise restrictions at the property line are 65 decibels in business zones and 80 decibels in industrial zones during daytime hours (7 a.m. to 11 p.m.). Several methods are available to reduce the noise at the property line, the most common of which is the strategic placement of fences to block and absorb the noise. Although no noise permit or clearance is required from the City of Boulder Environmental Enforcement Center, enforcement personnel would like to be informed of actions as plans progress, -and are willing to provide noise checks and work with a resource recovery developer to make sure the operation is within legal limits.

Noise pollution is an often overlooked form of environmental impact which has been shown to produce detrimental effects on the health and welfare of humans. While little is known about the case-and-site-specific impacts of potential resource recovery facilities in Boulder, a noise impact analysis should be performed if planning on either of the facilities progresses.

D. Solid Waste Generation and Permit Requirements

Solid wastes from resource recovery plants include combustion ash and particulate matter recovered by air pollution control devices. These wastes can produce undesirable leachates when disposed of in a landfill. Although data are scarce, fly ash particulate from waste incinerators may contain hazardous trace elements such as cadmium, lead, beryllium and mercury.

Under the Resource Conservation and Recovery Act (RCRA) of 1976, solid (nonhazardous) wastes are to be regulated primarily at the State and local levels. Under current circumstances, a Certificate of Designation would have to be issued by the Boulder County Commissioners if a new landfill site were to needed for waste disposal. The State Health Department would also have to approve the siting, engineering, and operational plans for any new landfill. If existing landfills are used for waste disposal, the site must be one that has already been issued a Certificate of Designation and is being operated according to minimum RCRA and State rules and guidelines (see Figure 6 for a schematic representation of the Certificate of Designation process).

Preliminary (not case-or site-specific to Boulder) data indicate that hazardous (under the meaning in RCRA) wastes may be contained within solid wastes generated from resource recovery processes. If this is the case, the waste disposal situation will become extremely more complex, and may prove to be a project fatal flaw. Hazardous wastes are generally regulated by the Federal Government (the EPA), although states can take over regulatory, administrative and enforcement responsibilities with an EPA-approved program.[1] Hazardous wastes are regulated from "cradle to grave" (from generation through transportation, storage, and disposal) under RCRA, and required actions may involve reporting requirements (to the regulatory authority), manifest requirements (to track the waste from cradle to grave) and permit requirements (an approved disposal facility). The RCRA hazardous waste program is still evolving, and early indications from the Reagan administration provide for substantial regulatory changes. Under current circumstances, disposal sites for hazardous wastes would require (like solid non-hazardous wastes) a Certificate of Designation from the County Commissioners. It is uncertain if a current exemption (pending further study) for utility and other wastes from the RCRA non-hazardous waste program would apply to resource recovery facilities.

E. Other Environmental/Regulatory Concerns

Other permits, approvals and clearances beyond those three listed above would undoubtedly be required before a resource recovery facility could begin operation. These may include such items as wastewater discharges (regulated by the state under authority granted to EPA in accordance with the Clean Water Act), and building, plumbing and electrical permits. Additionally, care must be taken to avoid environmental and safety problems associated with fires, explosions and pathogens contained within the waste streams.

---

[1] Colorado has indicated a desire to gain primary hazardous waste responsibility from EPA and is in the process of preparing a state program which would be approved by EPA.

F. A Regulatory Compliance Strategy

As briefly discussed previously, environmental and regulatory considerations may play a major part in overall project feasibility. At this early stage in project planning, the most serious potential fatal flaws are the probable need for an air emission offset and the uncertainty surrounding hazardous wastes. Further study needs to be performed during the future planning stages to determine the overall impact of regulatory considerations. In this regard, the following steps are recommended:

- once more detailed project plans are formulated, regulatory agencies on all governmental levels should be contacted;[1]
- meetings should be held with these agencies, with the applicant providing as much project data and information as possible in an open and honest exchange;
- issues, requirements and uncertainties should be identified early with each specific agency, with the applicant confirming verbal discussions and requesting answers to questions in writing; and
- involved agencies should be informed of all project actions and changes in plans as they occur.

---

[1] In making agency contacts, it is very possible that some minor permit, clearance or approval authority may be overlooked. Therefore, the applicant is encouraged to communicate with others proposing resource recovery projects, hire specialists in regulatory compliance, and/or contact as many agencies as possible (even those that may not visibly have a regulatory resource recovery role).

G. Risks of Hazardous Substances in the Waste Stream[1]

Questions have been raised about potential risks in the workplace from hazardous substances which may be contained in the waste stream of resource recovery plants. Since these systems are new, the consequences of hazardous substances in resource recovery systems are currently not well developed in relation to occupational health and safety factors. This section describes each of these hazardous substances and reviews some of the associated ongoing research and regulatory activity.

As municipal solid waste is processed within resource recovery facilities, workers are exposed to bacterial, fungal, and virological pathogens contained in the waste stream. Solid waste contains human and animal fecal matter due, for example, to the use of disposal diapers and the disposal of animal litter. Good data on the impact of the pathogens on the health of workers are not available. The EPA is funding research on pathogens in resource recovery plants by the Midwest Research Institute. This preliminary study is expected to produce a qualitative assessment of potential problems with pathogens and suggest what in-plant control measures can be implemented.

Processing solid waste produces considerable dust and because of the variety of materials in solid waste, there is additional concern about specific substances such as asbestos, metals, and other toxic substances. Obviously, dust control measures and personal protective equipment for workers in resource recovery plants need considerable attention on the part of workers, managers, and regulators.

Municipal solid waste occasionally contains dynamite, gunpowder, flammable liquids and gases, aerosol cans, propane, butane, and gasoline fuel containers, and other explosive and flammable materials. When such substances are shredded or processed in resource recovery facilities explosions can occur. Both refuse derived fuel and modular incineration facilities are designed to withstand mild explosions by constructing processing units with hinged walls and tops or other conduits to allow rapid venting of exploding gases. Explosion suppression/extinguishing systems, water spray, or equipment isolation are other means of reducing explosion damage. Manual or automated surveillance of input material is utilized in some facilities, but cannot be expected to remove all explosive substances.

---

[1] Source: OTA, Material and Energy from Municipal Waste, pp. 102-107.

Additional research in minimizing the potential of explosions and the damage resulting from explosion is being conducted by resource recovery manufacturers and by the Federal government (OSHA).

APPENDIX IV

NOTTINGHAM, NEW HAMPSHIRE FRAMEWORK FOR DEVELOPING THE COSTS OF RECYCLING

NOTE: This appendix is an excerpt from "Economics of a Small Rural Town Recycling System: Implications of a Case Study[1]". It presents the methodology utilized to determine recycling costs and revenues for a recycling system developed in Nottingham, New Hampshire. The town of Nottingham developed a dropoff center system in the early 1970's consisting of the following:

1. A manual baler for newspaper,
2. A shredder for manually fed cardboard and manually fed mixed paper,
3. Manual sorting of glass followed by glass crushing,
4. A ferrous/non-ferrous metal separator followed by a "tin" crusher (ferrous stream) and an aluminum crusher (non-ferrous stream).

This appendix develops specific capital and operating costs, transportation costs, and revenues for each of the materials recycled. The appendix develops a framework for determining these costs which can be utilized by other communities.

The authors of the report concluded that labor time and machine time (electricity usage and cost) represent the operating costs as they are the most dominant variables and are the easiest to quantify. Capital costs, transportation costs, and market revenues were developed for Nottingham in a more straight-forward manner.

The Nottingham report also includes the results of a weighing survey of household wastes to estimate the average daily quantity and composition of waste that might be expected from rural households under a source separation recycling system and a survey of households to determine residents' attitudes, toward the recycling system.

---

[1] Tichenor, R., Jansen, E.F. Jr., and Pickering, T., 1975, Economics of a Small Rural Town Recycling System: Implications of a Case Study: Durham, New Hampshire, University of New Hampshire, 46p.

Chapter IV of this report presents estimates of input requirements per ton for the processing of each material recycled in a Nottingham-type plant based on observed average input usage per ton for each process. It also examines the labor and electrical cost implications of the estimated requirements. In this appendix, additional information is assumed for a hypothetical town to illustrate a relatively simple framework for integrating information from Chapter IV with information from outside the report to approximate recycling costs and net costs for a Nottingham-type plant in a particular town.[1]

For estimation purposes, the sum of production labor and electrical costs for a Nottingham-type recycling plan may be viewed as roughly equivalent to what economists refer to as variable costs (i.e., costs for which the total varies directly with output levels). Appendix Table I-1 illustrates computational procedures for an approximation of variable cost per ton of recycled material. It is assumed that planners for the hypothetical town have determined that, given the resident and commercial population of the town, the expected composition of recyclables to be processed at the town facility is that given in Column 4 of that table.

It is further assumed that the appropriate wage and electrical rates are $3.00 per hour and $.06 per killowatt-hour, respectively. Multiplication of those rates by the estimated labor and electrical requirements given in Table 2 of Chapter IV yields the labor and electrical costs per ton for each material which are given in Columns 1 and 2 of Appendix Table I-1. Summing these for each material yields an estimate of variable cost per ton for that material (Col. 3). Multiplying the variable cost per ton for each material (Col. 3) by the percentage that each material is of total recycled waste in the town's composition (Col. 4) and summing these weighted figures (Col. 5) yields $15.19, the estimate of variable cost per ton of recycled material for the hypothetical town.

The annual amortization on the building and equipment plus annual overhead expenses can be viewed as equivalent to what economists refer to as fixed costs. It is assumed that the planners for the hypothetical town have determined that a Nottingham-type recycling plant can be constructed and equipped in that town for the costs itemized in the first

---

[1] To insure that they are not unreasonable, assumptions about wage and electrical rates, composition of recyclables, prices for recyclables, and initial costs of the building and equipment are based on information from Nottingham supplied to us by R and C, Inc. Assumed wage and electrical rates are those that applied in Nottingham during the study period. The assumed composition is based on sales data (and estimated accumulation of unsold aluminum) through early November, 1974. Assumed market prices are a simple average of prices received by (quoted to the case of aluminum) Nottingham through mid October, 1974. Assumed initial capital costs are those paid in Nottingham. However, due to other purely hypothetical factors in the example, it cannot be interpreted as depicting Nottingham's actual experience.

Appendix Table I-1

Computation of Variable Cost Per Ton of Recycled Material for Hypothetical Town

Material	(1) Labor Cost Per Ton	(2) Electrical Cost Per Ton	(3) (1) + (2) Variable Cost Per Ton	(4) Percentage Recycled Material	(5) (3) X (4) Contribution to Variable Cost Per Ton of Recycled Material
Newspaper	$ 14.10	$ .003	$ 14.10	12.4%	$ 1.75
Cardboard	48.60	1.72	50.32	6.7	3.37
Mixed Paper	25.80	1.21	27.01	10.0	2.70
Glass	6.90	.06	6.96	56.1	3.90
"Tin" Can	21.00	1.11	22.11	14.2	3.14
Aluminum	53.40	1.94	55.34	.6	.33
		Variable Cost Per Ton of Recycled Material			15.19

Reproduced from best available copy.

column of Appendix Table I-2, and that they have decided that life expectancies are as shown in the second column of that table, that annual amortizations are adequately approximated by the formula given at the bottom of that table, that the current municipal bond rate of 7% is the appropriate interest rate, and that annual overhead expenses (including an allowance for maintenance and repair expenses) will be about $2,000. As indicated in Appendix Table I-2, the resulting total annual (in-plant) fixed cost estimate is $5,722.63.

Together the computations of Appendix Tables I-1 and I-2 imply the following approximations of in-plant cost functions:

A1) Total Annual (in-plant) cost = $5,722.63 + $15.19 Q

A2) Annual (in-plant) cost per ton = $5,722.63/Q + $15.19

where Q = annual tonnage of recycled material. The hypothetical town's total cost and cost per ton can be approximated for various annual tonnages by substituting the tonnage for Q in the above equations.

Per ton cost estimates are probably the most useful for comparison with disposal alternatives. The second column of Appendix Table I-4 presents estimates of annual (in-plant) costs per ton computed with equation A2 for the selected annual tonnages given in the first column of that table. These are not, of course, the net costs per ton that should be compared with disposal alternatives. Net revenue per ton (revenue per ton minus the costs per ton of transporting materials to markets) must be estimated and subtracted from in-plant costs per ton to estimate net costs per ton. For our hypothetical town, it is assumed that the expected average market prices and transportation costs per ton for each material are those given in Columns 1 and 2 of Appendix Table I-3 yielding the net revenue per ton given in Column 3 of that table. Multiplying the net revenue per ton for each material (Col. 3) by the percentage that material is of total recycled material (Col. 4) and summing the weighted figures (Col. 5) over all materials yields $16.83, the estimate of net revenue per ton of recycled material given at the bottom of Appendix Table I-3. Subtraction of that amount from in-plant cost per ton at each of the selected tonnages in Appendix Table I-4 yields the net costs per ton given in the third column of that table.

If our linear approximations of production relationships in Chapter IV are thought to be adequate, this framework can be used to estimate annual recycling costs and net costs for real towns by substituting the appropriate information for the assumptions made for the hypothetical town. The estimated net costs per ton can then be compared with estimates from other sources of the net cost per ton of disposing of recyclables by the least cost alternative available to the particular town.

These estimates and comparisons can and should be made not only for the current annual quantity of recyclables but for a range of quantities that might accompany the potential growth or decline of the town within the life of the facility. Growth or decline may also cause changes in the composition, and prices (for inputs and outputs) are certain to change

Appendix Table I-2

Recycling Capital Costs At Nottingham, N.H. (1973-1974) and Illustrative Annual Fixed Cost Estimates for a Hypothetical Town

	Initial Cost	Estimated Life	Annual Fixed Cost 1/
Paper Shredder	$2390	10	322.65
Glass Crusher	1000	10	135.00
Can Crusher	3900	8	624.00
Magnetic Conveyor	800	8	108.00
Forklift	3800	10	513.00
Battery Charger	150	5	35.25
Batteries (30)	1500	10	202.50
Paper Baling Frame	15	2	8.03
Paper Baling Equipment	50	10	6.75
Glass Sorting Bins (3)	300	5	70.50
Glass Shipping Bins (12)	360	10	48.60
Metal Shipping Bins (12)	300	10	40.50
Paper Shredding Bin	30	10	3.35
Paper Shipping Bins (6)	300	10	40.50
Building (30x66x16) 2/	18,400	20	1,564.00
	33,295		3,722.63
Allowance for annual overhead expenses (Hypothetical Town)			2,000.00
Annual Fixed Cost (Hypothetical Town)			5,722.63

1/ Amortization on Equipment and Plant by the approximation formula: (Price/Life) + [(Price/2) x interest rate] using 7% for the interest rate.

2/ At Nottingham, this building houses the incinerator operation in addition to its recycling operation.

Appendix Table I-3

Computation of Net Revenue

Per Ton of Recycled Material for Hypothetical Town

Material	(1) Hypothetical Market Price Per Ton	(2) Hypothetical Transportation Cost Per Ton	(3) (1) - (2) Hypothetical Net Revenue Per Ton	(4) Hypothetical Composition	(5) (3) X (4) Contribution to Hypothetical Net Revenue Per Ton Recycled
Newspaper	$ 40.00	$ 3.40	$ 36.60	12.4%	$4.54
Cardboard	35.00	21.80	13.20	6.7	.89
Mixed Paper	11.90	14.70	-2.80	10.0	-.28
Glass	22.25	6.80	15.45	56.1	8.67
"Tin" Cans	25.00	11.40	13.60	14.2	1.93
Aluminum	200.00	20.00	180.00	.6	1.08
Net Revenue Per Ton of Recycled Material					$16.83

Appendix Table I-4

In-Plant Cost Per Ton and Net Recycling Cost Per Ton For a Hypothetical Town at Selected Annual Tonnages of Recycled Materials

Annual Tonnage of Recycled Materials Q	In-Plant Costs Per Ton (5722.63/Q) + 15.19	Net Costs Per Ton (In-Plant Cost Per Ton Minus Net Revenue Per Ton o 16.83)
Tons	Dollars	
200	43.80	26.97
400	29.50	12.67
600	24.73	7.90
800	22.34	5.51
1000	20.91	4.08
1200	19.96	3.13
1400	19.28	2.45
1600	18.77	1.94
1800	18.37	1.54
2000	18.05	1.22

over time. The simple framework suggested here can also be used to assess the impact of such changes by merely substituting various potential values of these variables into the framework for those values which are believed to be currently applicable.

APPENDIX V

Source: National Center for Resource Recovery, Inc.
November, 1978.

Reproduced from best available copy.

GLOSSARY
of Solid Waste Management and Resource Recovery

Like any emerging technology, resource recovery and modern solid waste management have developed a jargon all their own — often leaving the layman puzzled by a maze of incomprehensible terminology. "What's pyrolysis?. What's the difference between a dump and a sanitary landfill?"

In this new edition of the Glossary, the National Center for Resource Recovery, Inc., provides brief definitions for some of the more commonly used — but frequently misunderstood — terms. The definitions were prepared for lay readers, and should not be considered technically complete. Emphasis was placed on interpreting word meanings in the context of resource recovery and solid waste management, so that an interested reader without a technical background will find the terms to be helpful, understandable and relevent.

Aerobic Digestion: The utilization of organic waste as a substrate for the growth of bacteria which function in the presence of oxygen to reduce the volume of the waste. The products of this decomposition are carbon dioxide, water and a remainder consisting of inorganic compounds and any undigested organic material.

Air Classifier: A unit process in which mixed material is injected into a forced air stream and separated according to the size, bulk, density and aerodynamic drag of the pieces.

Aluminum: A light, strong, silver-colored metal, and the most abundant metallic element in the earth's crust. It is derived chiefly from the mineral bauxite.

Aluminum Magnet: See *Eddy Current Separator.*

Anaerobic Digestion: The utilization of organic waste as a substrate for the growth of bacteria which function in the absence of oxygen to reduce the volume of waste. The bacteria consume the carbon in the waste as their energy source and convert it to gaseous products. Properly controlled, anaerobic digestion will produce a mixture of methane and carbon dioxide, with a sludge remainder consisting of inorganic compounds and any undigested organic material.

"Back-End" System: Jargon for any of several processes for recovering resources from the *organic* portion of the waste stream. (Front-end processes separate and recover the *inorganic* portion from the incoming refuse.) Back-end system operations include refuse-derived fuel recovery, conversion to oil or gas, fiber reclaim, composting, conversion to animal feed, etc.

Ballistic Separator: A mechanical separation system in which the mixed material is ejected with a horizontal velocity, and segregated by the respective ballistic path or arc of each piece according to its mass and drag.

Beneficiation: The concentration, enhancement or upgrading of waste materials in a resource recovery processing system so that they may be more readily used as secondary materials. (See *Secondary Materials.*)

Biodegradable Material: Waste material which is capable of being broken down by bacteria into basic elements. Most organic wastes, such as food remains and paper, are biodegradable.

Biochemical Oxygen Demand (BOD): A measure of the amount of oxygen used by microorganisms to break down organic waste materials in water.

Collection Center: A place or facility designed to accept waste materials from individuals. This is usually for such specific items as glass bottles or cans. The term may also be used to mean a central receiving point for waste material collected by a government or private agency.

Color Sorting of Glass: A technique for sorting by color glass reclaimed from solid waste. Two experimental methods have been developed: (1) Optical sorting which compares light reflected from each piece with light reflected from a background standard. Successive passes, with different light source filters and standards, could be color selective. (2) Magnetic sorting which utilizes high-intensity magnetic forces on small glass pieces to sort the clear glass from the colored glass (which contains iron compounds).

Combustibles: Various materials in the waste stream which are burnable, such as paper, plastic, lawn clippings, leaves and other light, organic materials.

Commercial Waste: Waste material which originates in wholesale, retail or service establishments, such as office buildings, stores, markets, theaters, hotels and warehouses.

Composting: The natural conversion of most organic materials to humus by microorganism activity. Commercial methods speed up the action of aerobic microorganisms by mechanical mixing and temperature control, aeration and acidity. Composting is not effective on plastic and rubber.

Consumer Waste: Materials which have been discarded by the buyer, or consumer, as opposed to "in-plant waste," or waste created in the manufacturing process.

Cover Material: Sand and dirt used to cover compacted waste in a sanitary landfill.

Cullet: Scrap glass, usually broken up into small, uniform pieces.

Cyclone Separator: A mechanical separator which uses a swirling air flow to sort small particles according to their size and density.

Deinking: A process in which most of the ink, filler and other extraneous material is removed from printed waste paper or broke. This produces pulp which can be used along with varying percentages of virgin paper in the manufacture of new paper, including high quality printing, writing and office papers as well as tissue and toweling.

Densified Refuse-Derived Fuel (d-RDF): A refuse-derived fuel which has been compressed or compacted through such processes as pelletizing, briquetting or extruding, causing improvements in certain handling or burning characteristics. (See *Refuse-Derived Fuel.*)

Dewatering: The removal of water by filtration, centrifugation, pressing, coagulation or other methods. Dewatering makes sewage sludge suitable for disposal by burning or landfilling. The term is also applied to removal of water from pulp.

Dump: An open land site where waste materials are burned, left to decompose, rust or simply remain. Because of the problems which they create, such as air and water pollution, unsanitary conditions, and general unsightliness, dumps have been declared illegal (with varying moratorium dates) in all states.

Eddy Current Separator: A type of equipment used to separate aluminum and other non-magnetic metals through the use of electrodynamic induction of a magnetic field; *i.e.*, an alternating current is passed through a piece of metal in a specified manner causing the metal temporarily to become magnetic and making it possible to deflect it and separate it. Also referred to as "aluminum magnet" and electrodynamic separator.

Effluent: Solid, liquid or gas wastes which enter the environment as a by-product of chemical or biological processes, usually from man-oriented processes.

Electrodynamic Separator: *See Eddy Current Separator.*

Electrostatic Precipitator: A system for removing unwanted colloidal particles from a solution by passing the particles through an electrostatic field and then collecting the charged particles on collecting plate or pipe. Sometimes used in incinerators, furnaces and treatment plants to collect or separate dust particles.

Elutriation: The separation of finer, lighter particles from coarser, heavier particles in a mixture by means of a usually slow upward stream of fluid so that the lighter particles are carried upward.

Energy Recovery: A form of resource recovery in which the organic fraction of waste is converted to some form of usable energy. Recovery may be achieved through the combustion of processed or raw refuse to produce steam (*e.g.*, as a supplemental fuel in electric utility power plant boilers or as the primary fuel in incinerators), through the pyrolysis of refuse to produce oil or gas; and through the anaerobic digestion of organic wastes to produce methane gas.

Ferrous: Metals which are predominantly composed of iron. Most common ferrous metals are magnetic. In the waste materials stream, these usually include steel or "tin" cans, automobiles, old refrigerators, stoves, etc.

Fluid Bed Incinerator: An incinerator in which the waste is maintained in suspension in air by an upward controlled flow of the air. The bed of solids acts like a fluid when the upward air flow has sufficient velocity to float some of the solids. One such incinerator confines combustion within a bed of waste and sand supported on a perforated plane. Air is blown upward through the plate which churns the waste and sand into a turbulent mass. Volatile gases are collected above the bed.

Fly Ash: Small solid particles of ash and soot generated when burning coal, oil or waste materials. With proper equipment, fly ash is collected to prevent it from entering the atmosphere. Fly ash can be used in building materials, such as bricks, or disposed of in a landfill.

Fossil Fuels: Fuels, such as coal, oil and natural gas, which are the remains of ancient plant and animal life.

"Front-End" System: Jargon referring to processing of municipal-solid waste for recovery of materials (*e.g.*, metals, glass and paper). A front-end system also prepares the organic portion in a form readily usable in energy recovery, or back-end systems.

Froth Flotation: A process frequently used in the minerals industry whereby one type of finely divided solid may be separated from another by immersing them in a tank of water with an appropriate chemical surface active agent and introducing air bubbles at the bottom of the tank. The agent imparts to one material or the other a greater affinity for air than water, causing it to rise with the bubbles to the surface where it can be collected. This method is used to recover small particles of material such as sand-sized pieces of glass by separating them from rock and stone.

Furnace: An enclosed refractory or water wall structure equipped with grates. The furnace is the area in an incinerator where the preheating, drying, igniting and most of the burning of refuse takes place.

Glasphalt® : A highway paving material in which recovered ground glass replaces some of the gravel normally used in asphalt.

Glass: Vitreous material from the fusion of sand and soda ash, with adjuvant ingredients, common glass is impermeable, transparent, sanitary and odorless. Clear bottle glass is made basically by melting almost pure silica sand in furnaces at 2700°F. with burnt lime or limestone and soda ash. Crushed glass (cullet) has traditionally been added to make the mixture of raw materials more workable. Colored glass is usually obtained by adding small amounts of selected metals, salts or oxides such as iron salts or chromia.

Gravity Separation: The collection of substances immersed in a liquid by taking advantage of differences in density.

Hammermill: A type of crusher used to break up waste materials into smaller pieces or particles, which operates by using rotating and flailing heavy hammers.

Hazardous Waste: Waste materials which by their nature are dangerous to handle or dispose of. These materials include old explosives, radioactive materials, some chemical and some biological wastes, usually produced in industrial operations or in institutions. Not meant to imply that other wastes are non-hazardous.

Heavy Media Separator: A unit process used to separate materials of differing densities by "float/sink" in a colloidal suspension of a finely ground dense mineral. This suspension, or media, usually consists of a water-suspension of magnetite, ferrosilicon or galena.

Home Scrap: Scrap that is utilized within the plant where it originates. (See *In-Plant Waste.*)

Hydrolysis: A type of chemical reaction in which water acts upon another substance to form one or more entirely new substances. Hydrolysis is usually catalyzed by the presence of an acid or alkali. An example is the breakdown of cellulose to carbohydrates, or, further, to glucose. The products of the hydrolysis of cellulose may be fermented to produce ethanol.

Hydrapulper® : A large mechanical device used primarily in the paper industry to pulp waste paper or wood chips and separate foreign matter. The effect of pulping is to suspend finely divided cellulose fibers (and other matter) in water. This process has been incorporated in certain resource recovery systems.

Incinerator: A plant designed to reduce waste volume by combustion. Incinerators consist of refuse handling and storage facilities, furnaces, subsidence chambers, residue handling and removal facilities, chimneys and other air pollution control equipment.

Industrial Waste: Those waste materials generally discarded from industrial operations or derived from manufacturing processes.

Inorganic Refuse: Waste material made from substances composed of matter other than plant, animal, or certain chemical compounds of carbon. Examples are metals and glass. (See *Organic Refuse.*)

In-Plant Waste: Waste generated in manufacturing processes. Such might be recovered through internal recycling or through a salvage dealer. (See *Home Scrap, Prompt Industrial Scrap.*)

Institutional Waste: Waste materials originating in schools, hospitals, research institutions and public buildings. The materials include packaging materials, certain hazardous wastes, food wastes, disposable products, etc.

Jigging: A process used to segregate presized solid materials of different densities and operated by periodic pulsation of a liquid, usually water, through a bed of the mixture of solids, which tends to float the lighter solids.

Leachate: A liquid containing decomposed waste, bacteria and other noxious and potentially harmful materials which drains from landfills and must be collected and treated so as not to contaminate water supplies.

Litter: Solid waste discarded outside the established collection-disposal system. (Solid waste properly placed in containers is often referred to as trash and garbage; uncontainerized, it is referred to as litter.) Litter accounts for about two percent of municipal solid waste.

Magnetic Separator: Equipment usually consisting of a belt, drum or pulley with a permanent or electro-magnet and used to attract and remove magnetic materials from other materials. (See *Separation.*)

Manual Separation: The separation of waste materials by hand. Sometimes called hand-picking, manual separation is done in the home or office by keeping newspapers separate from garbage, or in a recovery plant by picking out certain materials. (See *Separation.*)

Materials Recovery: The initial phase — front-end — of a resource recovery system where recyclable and reusable materials are extracted from waste for sale. (See *"Front-End" System.*)

Methane: An odorless, colorless, flammable gas which can be formed by the anaerobic decomposition of organic waste matter or by chemical synthesis. It is the principal constituent of natural gas.

Microorganisms: Generally, any living thing microscopic in size including bacteria, yeasts, simple fungi, some algae, slime molds and protozoans. They are involved in the stabilization of waste materials (composting) and in sewage treatment processes.

Mixed Paper: Waste paper of various kinds and quality, usually collected from stores, offices and schools.

Modular Combustion Unit: A small, self-contained incinerator designed to handle small quantities of solid waste. Several "modules" may be combined in a plant, as needed, depending on the quantity of waste to be processed. (See *Incineration.*)

Municipal Solid Wastes: The combined residential and commercial waste materials generated in a given municipal area. The collection and disposal of these wastes are usually the responsibility of local government.

Newsprint: The kind or type of paper generally used for printing newspapers.

Nonferrous: Metals which contain no iron. In waste materials these are usually aluminum, copper wire, brass, bronze, etc.

Obsolete Scrap: Scrap derived from products which have completed their useful economic life.

Organic Refuse: Waste material made from substances composed of chemical compounds of carbon and generally manufactured in the life processes of plants and animals. These materials include paper, wood, food wastes, plastic, and yard wastes.

Packaging Materials: Any of a variety of papers, cardboards, metals, wood, paperboard and plastics used in the manufacture of containers for food, household and industrial products.

Paper: In a general sense, the name for all kinds of matted or felted sheets of fiber formed on a fine screen from a water suspension. More specifically, paper is one of two broad subdivisions (the other being paperboard) of the general term paper. Paper, usually lighter in basis weight, thinner and more flexible than paperboard, is used largely for printing, writing, wrapping and sanitary purposes.

Paperboard: Relatively heavier in basis weight, thicker and more rigid than paper. There are three broad classes of paperboard: (1) container board, (2) boxboard, and (3) special types such as automobile board, building board, tube board, etc.

Paperstock: A general term used to designate waste papers which have been sorted or segregated at the source into various recognized grades. It is a principal ingredient in the manufacture of certain types of paperboard.

Particulates: Suspended small colloidal size particles of ash, charred paper, dust, soot, or other partially incinerated matter carried in the products of combustion.

Plastics: Man-made materials, large molecules called "polymers," containing primarily carbon and hydrogen with lesser amounts of oxygen or nitrogen. Frequently compounded with various organic and inorganic compounds as stabilizers, colorants, fillers and other adjuvant ingredients. Plastics are normally solid in their finished state, but at some stage in their manufacture, under adequate heat and pressure, they will flow sufficiently to be molded into desired shape. Thermoplastics, such as polyethylene, polyvinyl chloride (PVC), polystyrene and polypropylene, become soft when exposed to heat and pressure and harden when cooled. Thermosetting plastics, such as phenolics and some polyesters, are set to permanent shapes when heat and pressure are applied to them during forming, and reheating will not soften these materials.

Primary Materials: Virgin or new materials used for manufacturing basic products. Examples include wood pulp, iron ore, silica sand and bauxite.

Prompt Industrial Scrap: Waste which is generated during a manufacturing operation. (See *In-Plant Waste.*)

Putrescible: Subject to decomposition or decay. Usually used in reference to food wastes and other organic wastes.

Pyrolysis: The process of chemically decomposing an organic substance by heating it in an oxygen-deficient atmosphere. High temperatures and closed chambers are used. The major products from pyrolysis of solid waste are water, carbon monoxide and hydrogen. Some processes produce an oil-like liquid of undetermined chemical composition. The gas may contain hydrocarbons and frequently there is process residue of a carbon char. All processes leave a residue of inorganic material. The gaseous products cannot be mixed with natural gas in principal distribution systems unless there is additional chemical processing. Applied to solid waste, pyrolysis has the features of effecting major volume reduction while producing storable fuels.

Recycling: A resource recovery method involving the collection and treatment of a waste product for use as raw material in the manufacture of the same or a similar product, *e.g.*, ground glass used in the manufacture of new glass. (See *Transformation.*)

Refractory Material: Incinerator lining material which resists the abrasion, spalling, and slagging effects due to heat and refuse material movement which are present in incineration.

Refuse-Derived Fuel (RDF): A solid fuel obtained from municipal solid waste as a result of a mechanical process, or sequence of operations, which improves the physical, mechanical or combustion characteristics compared to the original unsegregated feed product or unprocessed solid waste. (See *Densified Refuse-Derived Fuel.*)

Residential Waste: Waste materials generated in houses and apartments. The materials include paper, cardboard, beverage and food cans, plastics, food wastes, glass containers, old clothes, garden wastes, etc.

Residue: The materials remaining after completion of a chemical or physical process, such as burning, evaporation, distillation or filtration. (See *Sludge.*)

Resource Conservation: The reduction of the amounts of solid waste that is generated, reduction of overall resources consumed, and utilization of recovered resources.

Resource Conservation and Recovery Act of 1976: This law amends the Solid Waste Disposal Act of 1965 and expands on the Resource Recovery Act of 1970 to provide a program to regulate hazardous waste; to eliminate open dumping; to promote solid waste management programs through financial and technical assistance; to further solid waste management options in rural communities through government grants;

Reproduced from
best available copy.

and to conduct research, development and demonstration programs for the betterment of solid waste management, resource conservation and recovery practices.

Resource Recovery: A term describing the extraction and utilization of materials and values from the waste stream. Materials recovered, for example, would include metals and glass which can be used as "raw materials" in the manufacture of new products. Recovery of values including energy recovery by utilizing components of waste as a fuel or feedstock for chemical or biological conversion to some form of fuel or steam. (See *Recycling, Transformation.*)

Rising Current Separator: A unit process utilizing a form of elutriation which separates by a counter-current flow of water (or other fluid).

Rubber: An elastic substance obtained by coagulating the latex of various tropical plants and prepared as sheets and dried. It can then be modified by chemical treatment to increase its useful properties (toughness and resistance to wear) and used in tires, electrical insulation, etc.

Rubble: Waste materials made up mainly of fragments or pieces of rock or masonry, sometimes containing lumber or other construction materials.

Sanitary Landfill: A method of disposing of refuse on land without creating nuisances or hazards to public health or safety. Careful preparation of the fill area and control of water drainage are required to assure proper landfilling. To confine the refuse to the smallest practical area and reduce it to the smallest practical volume, heavy tractor-like equipment is used to spread, compact, and usually cover the waste daily with at least six inches of compacted dirt. After the area has been completely filled and covered with a final two- to three-foot layer of dirt, and has been allowed to settle an appropriate period of time, the reclaimed land may be turned into a recreational area such as a park or golf course. Under certain highly controlled conditions the land may be used as a plot on which some types of buildings can be constructed.

Scrap: Waste material which is usually segregated and suitable for recovery or reclamation, often after mechanical processing.

Screening: A sieve-like device used to separate pulverized waste material into various sizes. Two or more stages of separation may be used, each stage having a different hole size in order to separate material by size. (See *Separation.*)

Scrubber: A device for removing unwanted dust particles from an air stream by spraying the air stream with a liquid (usually water) or forcing the air through a series of baths. (See *Electrostatic Precipitator.*)

Secondary Materials: All types of materials handled by dealers and brokers that have fulfilled their useful function and usually cannot be used further in their present form or at their present location, and materials that occur as waste from the manufacturing or conversion of products.

Separation: To divide waste into groups of similar materials, such as paper products, glass, food wastes and metals. Also, used to describe the further sorting of materials into more specific categories, such as clear glass and dark glass. Separation may be done manually or with specialized equipment.

Settling Chamber: A mechanical collector which removes coarse particulate matter when the force of gravity pulls the dust to the bottom of the chamber. The air is introduced into the chamber at a very low velocity to allow the particulate to fall out more effectively.

Shredder: A mechanical device used to break up waste materials into smaller pieces by tearing and impact action.

Sludge: Waste materials in the form of a concentrated suspension of waste solids in water. One type of sludge is produced from the treatment of sewage.

Solid Waste: Discarded solid materials. Includes agricultural waste (*e.g.*, animal manure, crop residues), mining waste (*e.g.*, mine tailings), industrial waste (*e.g.*, manufacturing residues) and municipal waste. (See *Industrial Waste, Municipal Solid Waste, Residential Waste, Waste Materials.*)

Solid Waste Management: Conduct and regulation of the entire process of generation, storage, collection, transportation, processing, recovery and disposal of refuse.

Source Separation: The segregation and collection of individual recyclable components before they become mixed into the solid waste stream (*e.g.*, bottles, cans, newspapers, corrugated containers or office papers).

Spiral Classifier: A mechanical device for performing two types of wet separation of fine solids: (1) large solids are separated from small solids of approximately the same density; (2) higher density solids are separated from lower density solids of the same approximate size. The large or denser solids are delivered up the spiral, somewhat drained.

Steel: Commercial iron that contains carbon in any amount up to about 1.7 percent as an essential alloying constituent. It is distinguished from cast iron by its malleability and lower carbon content.

Tin-Free Steel (TFS) Cans: Cans made from low-carbon steel with a very thin anti-corrosion coating of chromium oxide rather than tin.

Transfer Station: A place or facility where waste materials are taken from smaller collection vehicles (*e.g.*, compactor trucks) and placed in larger transportation units (*e.g.*, over-the-road tractor trailers or barges) for movement to disposal areas, usually landfills. In some transfer operations, compaction or separation may be done at the station.

Transformation: A resource recovery method involving the collection and treatment (other than by biological or chemical means) of a waste product for use as raw material in the manufacture of a different product, *e.g.*, ground glass used to make brick. (See *Recycling.*)

Trash: Waste materials which usually do not include garbage but may include other organic materials, such as plant trimmings.

Trommel: A perforated, rotating horizontal cylinder which may be used in resource recovery facilities to break open trash bags, remove glass in large enough pieces for easy recovery and remove small abrasive items such as stones and dirt. Trommels have been used to remove steel cans from incinerator residue.

Urban Waste: A general term used to categorize the entire waste stream from an urban area. It is sometimes used in contrast to "rural waste."

Vibrating Screen: A mechanical device which sorts material according to size. The vibration serves to prevent clogging of the screen and to accomplish outfeed. Mechanical screens are used wet or dry, in single or multiple decks.

Virgin Materials: Any basic material for industrial processes which has not previously been used, *e.g.*, trees, iron ore, silica sand, crude oil, bauxite. (See *Secondary Materials, Primary Materials.*)

Volume Reduction: The processing of waste materials so as to decrease the amount of space the materials occupy. Reduction is presently accomplished by three major processes: (1) *mechanical*, which uses compaction techniques (sanitary landfill, etc.) and shredding; (2) *thermal*, which is achieved by heat (incineration and pyrolysis) and can reduce volume by 80-90 percent; and (3) *biological*, in which the organic waste fraction is degraded by bacterial action (composting, etc.). (See *Biodegradable, Composting, Incinerator, Pyrolysis, Sanitary Landfill, Hammermill, Shredder.*)

Voluntary Separation: The separation of glass bottles, food and beverage cans or newspaper by hand by individuals or groups of individuals, at home or in local collection centers.

Waste Materials (Solids): A wide variety of solid materials that may even include liquids in containers, which are discarded or rejected as being spent, useless, worthless, or in excess. Does not usually include waste solids found in sewage systems, water resources or those emitted from smoke stacks.

Waste Pulper: A pulping system designed specifically for waste material processing.

Waste Stream: A general term used to denote the waste material output of an area, location or facility.

Water-Wall Furnace: Furnace constructed with walls of welded steel tubes through which water is circulated to absorb the heat of combustion. These furnaces can be used as incinerators. The steam or hot water thus generated may be put to a useful purpose, or simply used to carry the heat away to the outside environment.

Yard Wastes: Grass clippings, pruning, and other discarded material from yards and gardens.